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ABBREVIATIONS. — D. = Discussion; I. = Illustrated.
Names of authors, etc., are printed in *italics*.

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FIRE PROTECTION ENGINEERING.

BY GEORGE VELTEN STEEB.

[Read before the Civil Engineers' Club of Cleveland, November 13, 1906.]

FIRE Protection Engineering, upon which I have been asked to speak to-night, is a natural evolution consequent upon the enormous waste by fire; for, while we are told that there can be no absolute destruction of matter, yet when we realize that during a period of twenty-one years from 1885 to 1905 inclusive, over $1 750 000 000 of property has "gone up" in smoke and flames in the United States alone, and been absolutely destroyed as far as its original purposes in the economy of the country are concerned, and that the smoke and flames produced have not served any useful purpose to mankind, and that the replacing of this property does not augment values, conditions, structures, stocks and other materials, and withdraws from other purposes vast sums of money, we must confess that in some respects matter is destructible. In consequence of this great destruction of values but one thing presented itself to the insurance interests other than practically prohibitive rates for insurance, and that was how best to conserve the interests of mankind at large by preventing the necessity of the duplication of man's labors on account of fires; and this gradually, through a long period of years, resolved itself into the technical subject of fire protection. The first step in the evolution consisted of inspection work directed only toward the modification of the common and inherent hazards, and was conducted by individual companies through non-technical men as a general rule. This was followed by inspection work in the interest of groups of companies

for the purpose not only of modifying the common and inherent hazards, but of eliminating all possible hazards, this work being done by a few technical men in specific branches and by men more or less trained in the general work by experience in the field only. Later developments have resulted in the organization of a national association of all persons interested in the science of fire prevention and fire protection, which takes up the modification and elimination of all hazards, proper construction and fire prevention and protection as a science, standardizes the various subjects specifically and formulates rulings on them which are the accepted standards in the United States and Canada, this work being done by technical men on specific subjects, by technical men trained in the inspection work, by thorough investigation and experimental work, by the application of the various rulings, by analyzing statistics of fire losses from particular causes, etc.

Fire protection engineering reaches far beyond the question of the loss ratio to fire insurance companies; it upbuilds the financial stability of the community and of the individual, for in a community subject at all times to a Chicago, Boston, Baltimore, Toronto or San Francisco conflagration, there exists the possibility of the ruin of the municipality as an important factor in the commercial world, the financial ruin of many an individual and firm and corporation, and a serious retardation of the material progress of the community for a considerable time; and in many indirect as well as direct ways the destruction of the manufactories, commercial interests and homes of citizens is of far-reaching consequence to a municipality. The interests of the community and of the individual are as much conserved as are the interests of the fire insurance companies; for, besides adding to their financial credit, a superior class of construction and protection not only presents a more esthetic appearance and stable condition, but reduces outlay, especially the items of repairs and insurance, by its greater durability and resistance to fire reduction possibilities.

Fire insurance engineering not only seeks the best methods for the extinction of fires, but seeks to eliminate or at least reduce to a minimum their causes, to provide methods of confining a fire to a unit (whether the unit be a block of buildings, a single building, a section, a room or a closet), and to reduce the possibilities of large losses; it involves construction, the reduction and elimination of common as well as inherent and external hazards, fire-fighting apparatus and appliances for the individual plant and

the municipality, and the standardization of construction and materials and installations; and it is so far-reaching as to involve the application of (and in many cases an intimate knowledge of) chemistry, architecture, construction, civil, mechanical, hydraulic and electrical engineering, processes of manufacturing and materials used in manufacturing; in fact, one may well say that there is no class of technical work into which it does not at one time or another enter.

To best explain what fire protection engineering is, is to give an idea as to what it has accomplished and what it is doing, for, covering such a wide range of scientific, technical and ordinary subjects as it does, it is impossible to "lump" the various ramifications of investigations, experiments, rulings and standards under one heading, as this would give but an indefinite and confused idea of this profession; therefore, in considering the individual subjects which I shall touch upon, I shall, in a general way, endeavor to indicate the results that have been accomplished, and point out how the work is being carried on, and how and where the standards and rulings are made, for this is an exact science, governed by rules and standards based on experiment, experience, investigation and statistics.

Wherein fire protection engineering is applicable can be illustrated by a view of the *general* and the *specific* propositions involved. For instance, consider the application of fire protection engineering to a building or a group of buildings of a single plant from its inception to its completed condition as an occupied property.

General propositions follow.

Preliminary: Specific standards are applicable to the architects' plans, whether for a "fireproof," "mill" or ordinary construction, a theater or a car barn, in respect to thickness of walls, subdivisions, fire breaks, types and construction of fire doors and shutters or wired glass for the protection of individual sections from each other or from surrounding buildings, etc.; and to construction in respect to the character, quality and strength of bricks, mortar, cement and concrete, masonry, lumber, carpenters' work, wrought and cast iron, steel and cast steel, etc.

Installation of permanent furnishings: Lighting and heating, both as to construction and location of artificial and natural gas, gasoline gas, acetylene gas, vapors for lighting, electric lighting, steam pipes and stoves, are all covered by rulings and requirements, and receive direct attention from inspectors or examiners.

Fire extinction appliances and apparatus: The character of the building or group, its location, its occupancy, etc., determine the question whether it will be necessary to have a fire pump, outside mains, yard fire hydrants, outside hose, outside hose houses and equipment, inside standpipes and hose, private fire brigade, automatic sprinklers, outside open sprinkler heads, chemical extinguishers, water pails and casks, blankets, sand, steam jets, automatic fire alarm systems, etc.; also the location and size and quantity or number of each of these.

Equipment of the building for its occupancy: There are specific rulings as to construction, location and installation of dry kilns, shavings vaults, waste picker discharge rooms, grain and other dryers, grain elevator heads, blower systems, fuel oil systems, gasoline and gas engines, supplying oils and benzene to mixers, systems for storing volatile fluids, automatic journal alarm systems, distance of stacks, furnaces, cupolas and other heat-producing appliances from combustible materials, metal cans for waste and for ashes and rubbish, protection of shaft and belt openings in walls, care and handling of benzene, gasoline and other volatile fluids, board scrapings, shavings, sawdust, polishing wheels, dust and fiber, packing materials, chemicals, and as to watchmen and watchman's time detectors, and so on to an almost unlimited extent,— all subjects of investigation at each risk by the inspectors and engineers.

Specific propositions may be presented by reference to the more important points of the rules and requirements promulgated and accepted as standard.

Construction: " Fireproof,"—strength, character and proper protection of metal members, cutting off of vertical openings, etc.; " mill " construction, avoidance of all concealed spaces and vertical openings, walls, cornices, floors, posts, stairways, elevators, flues, partitions, timbers, methods of setting timbers in walls and for floor supports, divisions of buildings, etc.; theaters, — proscenium wall construction, fireproof curtains, skylights, fly galleries, stairs, etc.; car barns for electric railways, materials, divisions, etc.; ordinary hollow space type of construction, — chimneys, sheathing, cornices, skylights, protection of vertical openings, etc.; generally, — fire doors and shutters, wired glass and the construction of frames for wired and prism glass used as a fire retardent, and almost all points in construction as to types and materials and parts, etc.

Permanent furnishings: gasoline, vapor, gas lighting machines, lamps and systems, kerosene oil pressure systems, acety-

lene gas machines and storage of calcium carbide, electric wiring and apparatus, electrical fittings, gasoline stoves, steam pipes, boilers, hoods for cooking ranges, boiler stacks.

Fire appliances and apparatus, for construction as well as installation of steam fire pumps, electric fire pumps, rotary fire pumps, steam pump governors and auxiliary pumps, hydrants for mill yard use, 1.25 in., 1.5 in. and 2.5 in. unlined linen fire hose for use inside buildings, 2⅝ in. cotton rubber lined hose for mill yard use, hose houses for mill yards, private fire departments, sprinkler equipments (automatic and open systems), stationary chemical fire extinguishers, carbonic acid gas, hand fire extinguishers, fire pails, sand pails, signaling systems used for the transmission of signals affecting the fire hazard, auxiliary fire alarm systems, etc.

Equipment of the risk for its occupancy: automatic journal alarms, gas and gasoline engines, storage and use of fuel oil and for the construction and installation of oil-burning equipment, systems for storing 250 gal. or less of fluids which at ordinary temperature give off inflammable vapors, construction and installation of grain dryers, coal gas producers (pressure and suction systems), waste cans, ash cans, refuse barrels, safety cans for benzene and gasoline, electric fire alarm thermostats, etc.

In the application of fire protection engineering to the municipality there are rules and specifications for the protection of a building against its neighbors by fire walls, fire shutters, wired glass, etc., and for water supplies, capacity of reservoirs, standpipes and pumps, sizes of mains, character and quality of the fire-fighting apparatus, etc. At this point it seems well to call attention to some specific features in one of the latest phases of fire protection engineering, that is, the investigation and listing of needed improvements in public water service, fire alarm service, fire department service and building codes, as now being conducted by committees of experts under the direction of the National Board of Fire Underwriters. Cleveland has been lately investigated by such a committee and the defects found in the various departments have been listed, and proper remedies for undesirable conditions have been pointed out, and it will be regrettable if the more important of these suggested improvements are not acted upon at once and carried out in spite of any false pride or sentiment on the part of any official or citizen, for they are based upon the opinion of men particularly well qualified to pass upon such subjects, and are for the best interest of the city, and are not an excuse to increase rates of insur-

ance, as some ill-informed citizens have stated. Another local subject is the laying of high-pressure mains at this time for fire-fighting in our city, and we can only hope that the work will be supplemented by the proper installation of an adequate high-pressure pumping plant, for while the present proposition is of great value, still it can only be considered a "makeshift," and not an adequate, high-pressure water system. I trust that you gentlemen who have the interest of this city at heart will in all ways bring your influence to bear upon the carrying out of the improvements and extensions referred to.

The rulings and requirements in use are not the production of the fire insurance interests alone, for in the committees appointed to formulate them are representatives identified with the specific subjects treated of; and while they are put forth by the National Board of Fire Underwriters, they are the results of the investigations, tests, statistics and experience of the National Board of Fire Underwriters and its expert committees, of the National Fire Protection Association, of the individual fire insurance companies and of the manufacturers and installers of the various appliances, etc. As the rulings are determined upon by the National Fire Protection Association, a glance at its *personnel* will not be amiss. It is composed of persons interested in the science and in the improvement of methods of fire protection, and has 52 active members, consisting of insurance boards, insurance associations, national institutes, societies and associations interested in the protection of life and property from losses by fire (amongst whom we find, besides the insurance interests, the American Institute of Architects, American Society of Mechanical Engineers, American Warehousemen's Association, American Water Works Association, International Association of Fire Engineers, National Electrical Contractors' Association), 724 associate members who are individuals engaged in the fire insurance business and individual members of the organizations represented in the active membership, and 267 subscribing members who are individuals interested in the protection of life and property against losses by fire, and in this class any one is eligible. It is from this membership that committees are formed, and it is after discussing the conclusions of these committees at the annual meetings of the Association, in open meetings, that the rules and requirements are finally formulated and promulgated; hence the faults in construction and equipment, the causes of fires, etc., as found by the insurance interests through inspections and statistics, are thoroughly and

scientifically considered and discussed and passed upon by all the interests involved in any one branch of the subject.

While the rules give definite instructions as to the materials, sizes, general character of parts for construction of standards and types of fire pumps, hydrants, hose, chemical extinguishers, gasoline and acetylene gas machines and lamps, etc., they are so drawn as not to interfere with the individuality of any special design which covers the points named in the rules in a correct manner; they simply embody the essential features of construction of the various apparatus and leave it to the manufacturer to make his own particular form and design.

The investigation and testing of fire resisting materials, electrical devices, fire extinguishing appliances and other devices and materials, are conducted in a specially constructed fireproof building known as the Underwriters' Laboratories, under the supervision of members of the National Fire Protection Association, and unless the specifications for construction and workmanship are complied with and the tests show certain conditions and results, the device or material being investigated and experimented upon or tested will not receive the approval of the Association, cannot be listed as an approved device or material and will not be accepted in practice. Besides this laboratory there are several others employed in the same class of investigations and tests, but these latter laboratories have not authority to approve or accept devices, etc., for the general insurance interests.

While I have not made this paper as specific as some of you gentlemen would desire, it has only been the necessity of confining myself to a reasonable length of time that has prevented a more extended and comprehensive presentation of some of the various phases, but I trust that I have made it clear that in fire protection engineering we have no hesitation in tackling common or inherent or exposure hazards, construction, installation and protection, whether it takes us "way up" or "way down"; that there is nothing within its province which is either too large or too small for consideration; that the conclusions arrived at are based on well-defined premises, with thoroughness and a full grasp of the subjects involved; and that this is a profession which redounds to the welfare of all people.

DISCUSSION.

DR. MILLER. — Mr. Steeb has presented in a very interesting manner facts which show that fire protection has been

studied very thoroughly and systematically by the underwriters, and their rulings are no doubt sufficient, but I wish that he had given us something more specific for the purposes of discussion.

Mr. Lane. — I would like to know just what Cleveland is doing in regard to the high-pressure system.

Mr. Steeb. — A couple of years ago the question of high-pressure water service was taken up in the city and a plan was made for protecting all the district from East Ninth Street down to the river, and I don't know how far the pipes went south, but all the way to the lake and then running out to the manufacturing district along the lake. This was brought up to the water works department, and they determined that the outlay of money would be too great to undertake such a system, but by insistence and eliminating all the lines running along the lake east from East Ninth Street we at last got them to agree to put in a system which will eventually make East Ninth Street the center of the high-pressure system. There is a 30-in. pipe being laid in East Ninth Street, which we hope ultimately will extend down to the Kirtland Street pumping station. From this 30-in. main, which is run through East Ninth Street, the 20-in. and 10-in. and various sizes pipes are now laid and being laid in the district between the lake, East Ninth Street and the river. There are two extensions which run down to the river and it is proposed in case of fire to attach fire tugs. The system is rather inadequate. It will be readily seen that it will be a makeshift, but it can also be seen that it will give us protection through the commercial district.

Mr. Lane. — I notice in laying the pipes on Superior Street there were some 3-in. pipes laid on top of the fire pipes. Did they have anything to do with the high-pressure service?

Mr. Steeb. — I don't know. The smallest pipe to be put in are two connections over towards East Sixth Street, and for a short distance there will be two sections of 4-in. pipe. This is the smallest pipe.

Dr. Miller. — It is possible some of the members of the city water works department are here as guests this evening, and we should be glad to hear from them or from any other members of the club.

Mr. Lane. — Will the entire amount of water received by the 30-in. come from the fire tug, or will the Kirtland Street pumping station do something?

Mr. Steeb. — At this time only the fire tugs.

Mr. Lane. — How many standard streams is that equal to?

Mr. Steeb. — I think we figured with the tugs that we could get 10 standard streams from 6 fire tugs.

Mr. Carroll. — I have been requested to ask Mr. Steeb regarding reënforced concrete building for mill stores as to their being absolutely fireproof.

Mr. Steeb. — No, sir, because we don't know what the concrete is made of and we don't know what the cement is made of. We don't know the mixture and how long it has stood. We have a committee of the National Fireproofing Association, and that committee made a report at the last meeting, but they are checking the subject up further. They have no statistics on concrete building, and while they are nominally fireproof, we cannot say that they can be depended upon.

Mr. Carroll. — I would like to ask Mr. Steeb's opinion as to the merits of the different kinds of hollow tile used in construction, viz., hard, semi-porous and porous.

Mr. Steeb. — We have no definite conclusions on them either. You see tile construction as we have it to-day only dates back a very few years and we cannot arrive at any definite conclusions on this experience. Our rulings are based on statistics and experience, and no insurance company takes its statistics as being worth anything unless it includes 7 to 10 years. We have no experience on this class of construction for that length of time. I have a case in mind of a coal mine lately. A hollow vitrified tile has been used for the construction of the power house. We had a fire in the mine the other day. The wall construction was hollow tile. There was a planking floor around the engines. There was a wooden roof with wooden sheathing. The roof burned and fell down, and the wall was badly cracked on the inside. The fire was not very large. There was a crack on the inside but none on the outside; simply an inside section of the facing was cracked. We have no real statistics. Take the cement and concrete blocks that are being made to-day. Any man can put up a two by four shack and get a little cement — it doesn't make any difference what kind — and he can get a little sand and make some tile block and build dwellings with them, and it is wonder that they don't fall down. There is no question but that they will fall down. Until you get a standard of mixture we can never have a standard for block.

Mr. Carroll. — In regard to mill-constructed buildings, I have been told that the board of underwriters will insure a mill-constructed building at a lower rate than one having a steel frame. Is this correct?

Mr. Steeb. — The types in each class are so varied it is hard for any one to state. You take a steel frame building, and if the members are not thoroughly protected, it is better to have a wooden frame building. The question of insurance rate has entirely to do with how each building is constructed. We have buildings here in this city that we call fireproof on which you can almost go and pick the tile off. You will find on the lower side of the I beams that they have thin pieces of tile. We find these conditions all through on account of poor covering to the metal member and also of the channelling of the fireproofing of the metal members for wires and pipes, and the covering of these channels with plaster on wire netting. In Baltimore a number of buildings were doubled up on account of this construction. As to mill construction, there is not a mill-constructed building anywhere in this section. There are a number of them in the East and quite a number now of new cotton mills in the South, but we have no mill-constructed buildings in this section. Because a man uses heavy timbers and solid post and has a double floor and has no hollow space in his walls, he says he has a mill-constructed building. In a mill-constructed building there are absolutely no openings in the floors.

Mr. ——.— I have seen it stated that it is impossible to construct a fireproof building. What do you think of it?

Mr. Steeb. — I don't know. It's hard to answer. If you will properly protect all metal members on bridge-constructed buildings, you can get a fireproof building, but you have to take the stairways out and the hatchways out, and would have to have the entire construction of steel. What would burn in the building would have to be eliminated. Because we call a building fireproof, we don't mean that the contents would not burn. I don't think we have any building that we can call absolutely fireproof. There is talk now of putting up glass buildings.

Dr. Miller. — Mr. Steeb had occasion to refer to the fact that the fireproofing in Baltimore was not very good. I noticed the same thing in connection with the San Francisco buildings at close range several weeks ago; in many buildings that were supposed to be fireproof the fireproofing fell away, the beams softened and the whole building collapsed finally. I also saw Baltimore after the fire, but the destruction at San Francisco is much more complete. One cannot imagine the conditions there. In 5 square miles I believe there were only three buildings that were not burned. These are the United States Post-office, the United States Mint and the United States Custom

House. The post-office was cracked a little, but not seriously. The fire did but slight damage; there is no doubt that they were well constructed in the first place and were fairly well provided with fire protection. However, to see these three buildings standing, and all around for a distance of nearly a mile on all sides burned down, was a striking illustration that reasonably good construction and good care are worth while. At Stanford University many buildings were flat on the ground. Only the older buildings were uninjured; the new buildings were wrecks, and the reason for it appeared to be due to the very poor quality of cement, mortar or whatever held the stones together. They were made of soft stone, and I saw hundreds of cracks in the buildings and not one crack through the stone; always in the joint. In San Francisco I remember seeing two structures equally high, both of them made of brick, one flat on the ground and the other standing without a crack, which shows that one had good mortar and the other poor mortar.

Mr. Lane. — I have looked over several reports of the San Francisco disaster, with probably 1 500 photographs, and our speaker to-night has spoken about concrete, saying he did not know much about it, but every one of those reports claims that the concrete reënforced construction gave the best account of itself of any of the building systems that went through the San Francisco disaster, that buildings that were constructed this way stood the best. There are two things that may be of interest in regard to the San Francisco fire. In the first place, the first fire was probably a small affair, and would probably have died out if some one had not started a fire in a stove where the chimney had been destroyed by the earthquake. This is shown by the photographs. The photographs taken show very plainly the progress of the fire toward the water front, and then show this one building taking fire, and there are some 40 photographs showing the fire doubling back and taking in the greater area. Another interesting point is this: There was a factory building of tile and brick, fireproof construction, with a large window area. The earthquake took one section out of the upper story. One interesting thing is that the building was burned on three sides and passed the fire successfully on account of the fact that it had metal sash and wire glass and 5 or 6 of the men stuck to it and stayed inside and put the fire out with water from a big tank in the building.

Dr. Miller. — In regard to Mr. Lane's statement that the fire would have been under control, etc., and that the

conflagration would have been limited, I can give no information. My impression is that the fire started in many places. At the time I left San Francisco they had not started any new buildings; no doubt many designs had been made. During the past summer one of our members was in San Francisco designing new reënforced concrete buildings. There is a great demand for ordinary engineering work, but not very much demand for the highest grade of engineers.

Mr. Palmer. — Is granite considered a good material for a fireproof building?

Mr. Steeb. — No, sir. We don't allow granite if we can prevent it. We would not have granite coping on a brick pier in a building.

Mr. ——. — Would you have sandstone?

Mr. Steeb. — Sandstone is better, because when it is heated it does not disintegrate. We prefer to have no stone on it.

Mr. Carroll. — I have noticed in reading various engineering papers that there is a great deal of difference of opinion as to whether reënforced concrete is better fireproofing material than hollow tile, and I notice that the *Fireproof Magazine*, published by the hollow tile trust, in all cases, of course, states that hollow tile is a better fireproofing material than reënforced concrete. I have not had time to sift all of these articles down so as to satisfy myself as to which is the better. I would like to ask Mr. Steeb if he knows of any literature that is impartial and treats each construction on its merits.

Mr. Steeb. — The magazine you refer to, the *Fireproof Magazine*, is gotten out by the people manufacturing that material. Of course in reënforced concrete construction we have a whole building built of reënforced concrete, whereas in fireproofing it is only applied to steel members to keep them from giving way. The building is not built of fireproofing appliances. It simply is a protection, so there is no comparison between the two. As to whether a block would simply disintegrate either by age or by the amount of water or heat any faster than reënforced concrete, we don't know. We are making tests, but they cannot be compared because they are used in entirely different ways. The construction of reënforced concrete gives us a better building than any we have yet had.

Mr. Lane. — There is one thing that may be of interest, and that is that the Taylor-Wilson shops at McKees Rocks, Pa., built with the side walls of reënforced concrete and a big arch sprung over the entire building, have succeeded in securing a

lower insurance rate than any other building in the Pittsburg district.

Mr. ——. — I would like to ask Mr. Steeb this question: Given two steel frame buildings, one fireproofed with tile construction, the other fireproofed with concrete, which would be considered the better risk?

Mr. Steeb. — The only construction of that kind that we know of would not exactly apply to your question, because we have no absolute concrete protection to steel members. The nearest approach to it is by using wire netting and then using cement upon the wire netting. I don't know why it has never been used, but I presume other ways were found to construct a steel frame and then all the members were thoroughly enclosed with concrete. It has never been done because all that would really make reënforced concrete construction. Members are used instead of rods; it would make a very expensive construction, so there is no such construction. The nearest to it is using some netting and then using cement upon that.

Moved by Mr. Palmer and seconded by Mr. Neff that the Club extend its hearty thanks to Mr. Steeb for this very interesting paper upon this important subject. Unanimously carried.

[Note.— Discussion of this paper is invited to be received by Fred. Brooks, 31 Milk Street, Boston, by March 15, 1907, for publication in a subsequent number of the Journal.]

THE USE OF SUCTION GAS PRODUCERS FOR POWER PURPOSES.

By N. T. Harrington.

[Read before the Civil Engineers' Club of Cleveland, January 9, 1906.]

Below will be given a short description of a suction producer, a discussion of the different classes of work to which it is applicable, with performances under different classes of service, general comparison with performances of other types of prime movers, a discussion of the best type of producer gas engines and a few remarks on plant arrangement.

A suction gas producer may be considered as having been evolved from a base-burner stove. Let us suppose a base-burner stove like Fig. 1. It will be seen that this stove consists of a magazine thimble, a bed of fuel, grate bars to support the fuel, the body of the stove lined with fire brick, vent to the smokestack outside the thimble and outside the fuel, and ash door as well as door above the fire through which the fire can be seen.

The body of fuel which is burning in such a stove is usually from 8 to 10 in. deep. Air, which is admitted through the damper of the ash door, passes through the grates and is sucked up through the fire by the draft in the chimney and passes out to the smokestack. This air, in passing through the fire, combines with the carbon of the coal to make a practically complete combustion, the gases going to the stack as result of this combination being CO_2, N and a small amount of CO, or unburned gas. There will also be some trace of hydrocarbon gases which are distilled off from the coal in the magazine forcing their way down through it and up the outside of the thimble to the stack. These will vary in quantity depending on the amount of volatile matter in the coals. With anthracite coals the volatiles usually amount to less than 6.05 per cent. by weight.

It will thus be seen that, with a base-burner stove, practically all the gases are burned, and as the object of a stove, of course, is to furnish heat, the more completely these gases are burned to CO_2 the more efficient is the stove. There will always be unburned gas with a base-burner stove, inasmuch as it is impossible to have the exact amount of oxygen distributed through the fire uniformly at every point, where it should be present to combine with the carbon.

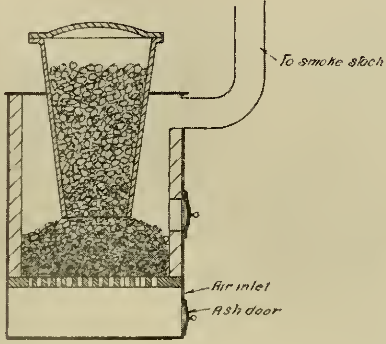

Fig 1
...se Burner Stove

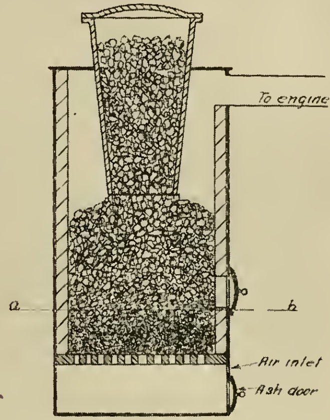

Fig 2
Suction Gas Producer

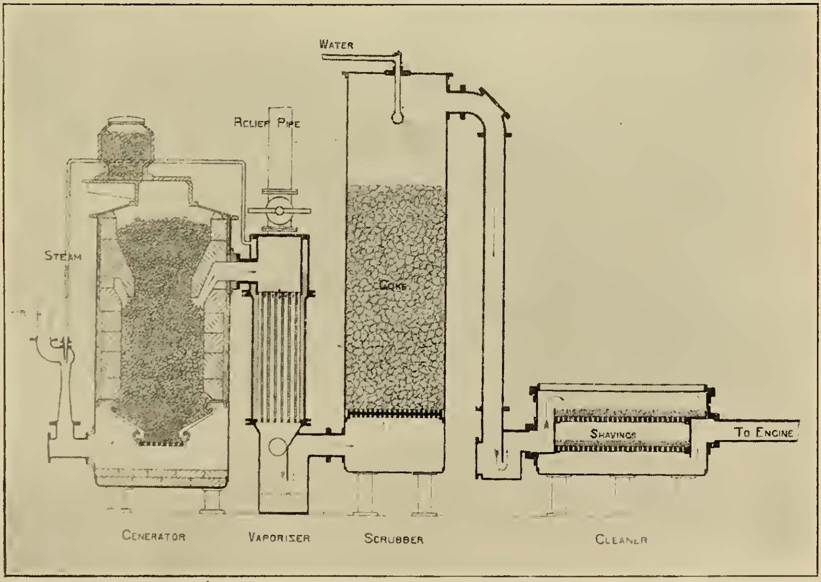

FIG. 3. ASSEMBLED PRODUCER WITH THE PIPE CONNECTIONS.

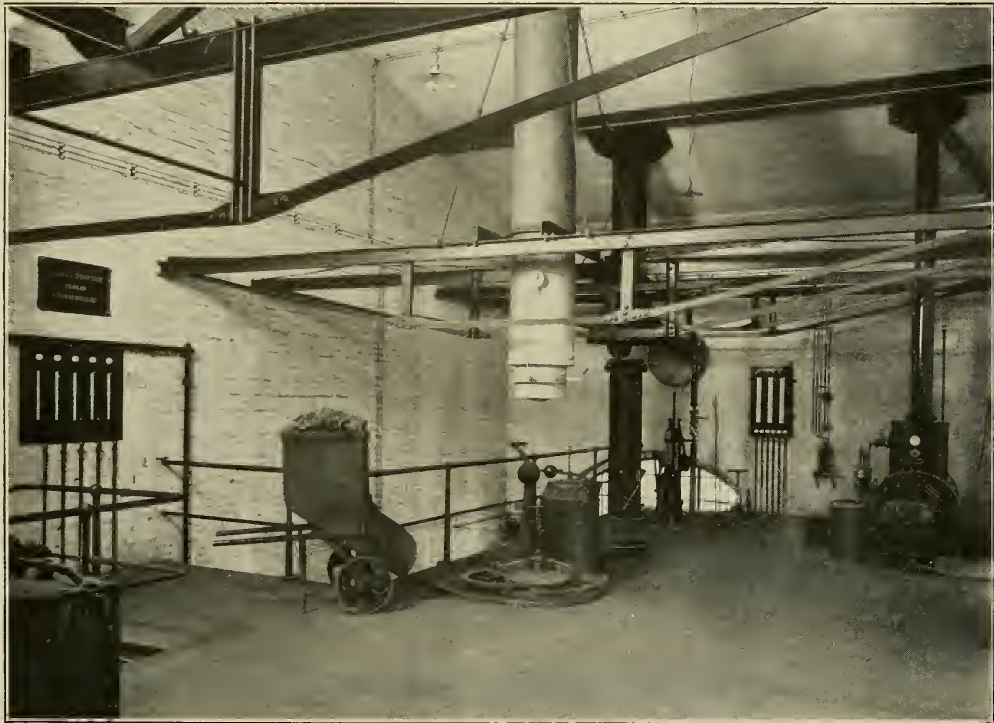

Fig. 4. Charging Floor. (600 H. P.)

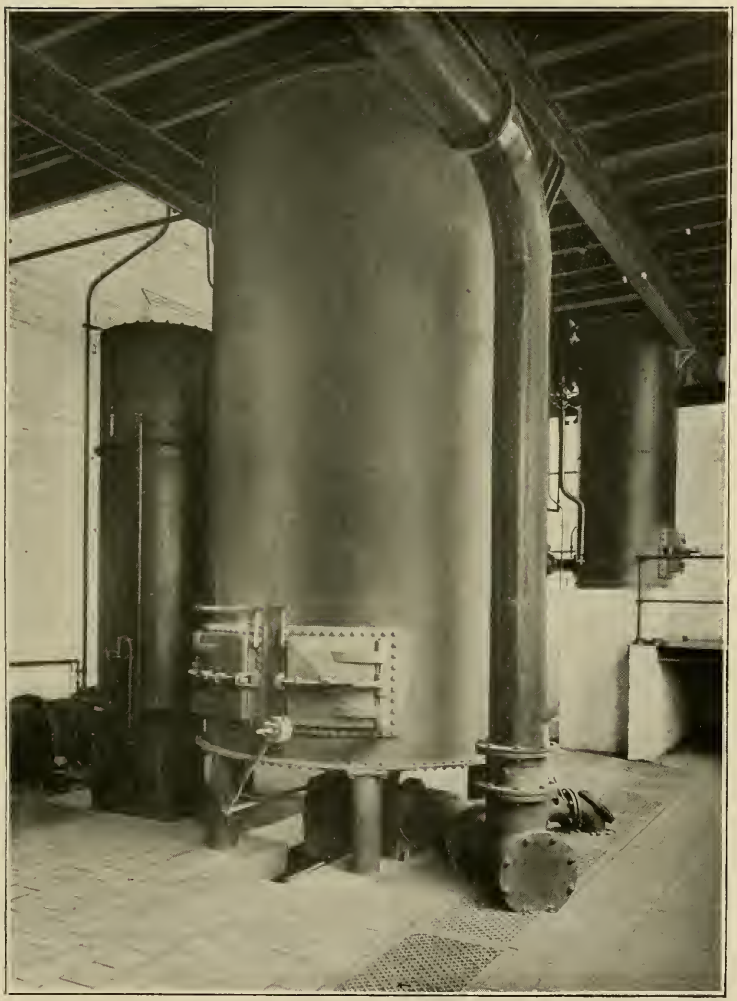

Fig. 5. 600 H.-P. Generator.

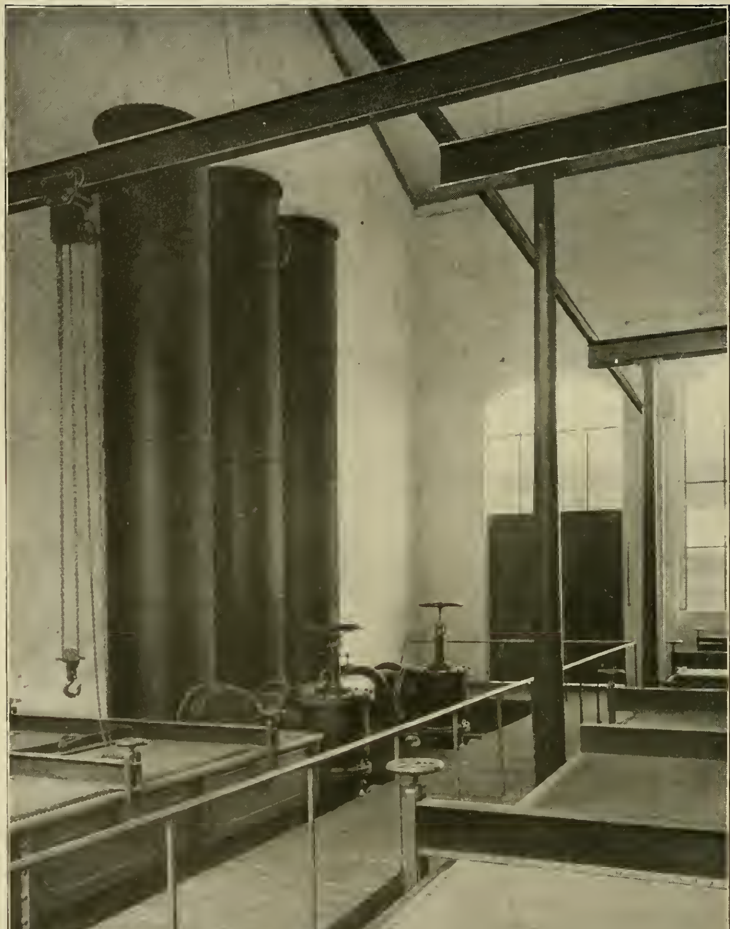

Fig. 6. Scrubbers.

With this fire it will be found that oxygen is present as oxygen all up through the mass of burning coal even up to the top of the fuel bed, and the combustion is occurring from the bottom of the fire up to the top of the burning mass.

What is necessary to turn this stove into a gas producer? In a gas producer we have the equivalent of a smokestack, viz., the suction from the engine, to draw the air in through the fire and the gases out through the vent. We have the same grates, the same thimble, the same outer shell with lining, ash door and damper, the only difference consisting in the fact that the depth of the fuel body, in a suction gas producer, is increased over that of a base-burner stove, as shown in Fig. 2.

Why, then, should this slight difference in the depth of fuel body make all the difference between generating a combustible gas, as in the case of a gas producer, and making a completely burned gas, turning most of the heat value of the coal into sensible heat, as in the case of a stove?

The reason is that it is only possible to make combustion occur with ordinary low drafts up through 8 or 10 in. of the fuel body. In a stove, as we have seen, the fuel body is only this deep and, therefore, the gas comes off completely burned. With a producer, however, up to a zone *ab* (Fig. 2), which is about 8 in. above the grate, we have a resultant gas made up of CO_2 and N as the product of combustion. The heat generated by the formation of this gas is confined within the walls of the producer and heats the fuel above the zone *ab* to an incandescent temperature. The CO_2 gas must pass through this incandescent fuel to find its way out to the engine and, in passing through this fuel, each molecule of CO_2 gas will pick up an atom of carbon, thus forming two molecules of CO gas. This CO gas passes out through a pipe to the engine with the N brought by the air into the producer, forming a combustible gas which can be later burned in the engine. This would be a most elementary sort of a gas producer, and by filling any base-burner stove up with coal to a depth of about 30 in. above the grates, a gas could be formed upon which an engine could be operated.

In the actual development of these producers several things were found necessary. A double valve was imperative at the top of the magazine to prevent the drawing in of air while putting in coal. The magazine thimble had to be made of fire brick so that it would not burn. Some means were found necessary to keep the temperature of the fire low enough so as not to burn the grates or form clinker, the most objectionable of these last two

being the formation of clinker. It was discovered that by admitting steam, with the air going in underneath the grates, not only could clinkering be prevented and the grates kept cool, but an actual increase in the thermal value of the gas could be made. This being due to the fact that by breaking up the steam in the combustion zone, by means of high temperature, the hydrogen and oxygen of the steam could be separated, the hydrogen going through the fire, as hydrogen, to enrich the gas, and the oxygen, being pure oxygen, serving to supply some of that required for combustion and making necessary a smaller quantity of air.

As a result of this maneuver less nitrogen would be brought in and, as nitrogen is perfectly inert, any reduction of the nitrogen in the final gas would serve to increase its thermal value provided the amounts of the other elements remained constant.

Gas generated in a producer, without the use of steam, would have a thermal value of somewhere around 70 B.t.u. per cu. ft. By using steam with the air admitted to the fire, the producer gas generated will immediately have a thermal value of 135 to 140 B.t.u. per cu.ft.

The clinkering in the fire has been reduced at the same time the temperature in the combustion zone is lowered, owing to the heat abstracted by the steam, the reduction in the amount of clinkering being due to the fact that the temperature has been kept below the fusing point of the ash in the coal. The reduction in temperature in the combustion zone also tends to increase the life of the grates.

Gases, other than steam, have been used for this purpose, CO_2 being the one from which the best results have been obtained. A certain amount of CO_2, obtained from some external source, can be put through the fire without causing it to go out; this CO_2, being broken up in the incandescent zone, like that from the combustion zone, forms CO. The gas resulting from such a process, however, has a much lower thermal value than that formed by the use of steam.

In passing these cooling gases through the fire, some automatic device must be used to proportion the amount of cooling gas so added to the amount generated by the producer; that is, when driving an engine under variable load, at certain times a great deal of gas is generated from the producer and at other times very little. Thus it is necessary to alter the amount of cooling gas to prevent quenching the fire under light loads.

Many devices have been developed for this purpose; it may be said that those are best which have the simplest construction and fewest working parts.

The gases from the gas generator will be found to be hot, having a temperature of between 800 and 900 degrees fahr., and also dirty, as they will carry with them fine dust from the generator and will also contain certain portions of tar, the amount of tar depending on that contained in the coal originally.

A cooler is, therefore, provided by which the gases are reduced in temperature. It was found that enough heat was contained in these gases to generate the steam necessary to cool the fire of the producer. This cooler, therefore, is formed in the shape of a vaporizer. There are many different forms of vaporizer, but perhaps the most common is that of a tubular heater, the water being admitted to the vaporizer and simply overflowing through a vent, the amount being adjusted to the maximum demand of the producer and, when loads are light, the excess flowing away. The vaporizer is not under pressure as regards steam, the steam being sucked away from it by the suction of the engine which draws it underneath the grates.

The gas being still dirty is then passed through a scrubber, which amounts to nothing more than a tank filled with coke over which is spraying water from a rose nozzle in the top. The gases enter at the bottom of the scrubber, pass up through the coke and out at the top. In this passage they are cooled down to the temperature of the water and any dust which they carry is deposited in the coke. This coke being continually washed down, is kept free from the deposited dust, the dust being washed out through a water-sealed trap and carried away

The gas is now clean and cool but wet and should, therefore, be passed through a cleaner or dryer. This cleaner usually consists of a tank with a removable top in which rest wooden grids having sawdust laid upon them; the sawdust takes up the moisture from the gas and it trickles down and out through the water seal to the sump. The last fine particles of dust are also deposited on the sawdust, a certain amount finding its way through the scrubber. The gas, after coming from the cleaner, is thus clean, cool and dry and is in suitable condition for use in the engine.

Figure 3 shows an assembled producer with the pipe connections. It will be seen that it consists of a little more than a high base-burner stove and three tanks. The whole system is under vacuum of about 1.5 in. of water, this vacuum being

caused by the suction of the engine; therefore no gas can leak out of the system. If any leak occurs in the mains it will be air leaking into the gas.

The producer can be charged with coal while running, the fire can be seen by opening the stoking door, grates can be shaken and ashes removed by opening the ash door, all without disturbing the operation of the producer, which is, therefore, continuous.

There are other types of producers which I will not take the time to discuss, one type being known as the "Pressure Producers" in which air is forced under the grates. There are many types of intermittent producers in which the fire is first blown hot with air and then cooled with steam, 70 B.t.u. gas being formed while blowing air and 360 B.t.u. gas while blowing steam. The pressure producer has the disadvantage that the fire cannot be seen or ashes removed while in operation; and the intermittent producers require close attention as the changes must be taken care of every one and a half or two minutes. The suction anthracite producer, therefore, for small plants has become very widely used. These producers have been built for plants up to 1 500 h.p. and operate successfully in this size. Such a size, however, is only possible where the cost of anthracite fuel or coke is less than that of bituminous coal — the suction producer not being as yet capable of burning bituminous coals or fuels containing tarry products, although experiments along this line show promise of success.

Figures 4, 5 and 6 show a 600 h.p. suction producer with vaporizer, scrubber and cleaner, also charging floor.

A blower is usually attached to a suction producer and, in ordinary sizes below 100 h.p., a hand-driven blower is sufficient for blowing the fire warm when starting up the apparatus. After the fire is hot and the gas begins to generate, the blowing is discontinued and the engine can be started, after which the suction of the engine is sufficient to keep the fire warm.

A suction producer can be used not only for power purposes, but for heating purposes, as it forms a combustible gas efficiently, the efficiency of the producer being 80 per cent., which is better than most boiler efficiencies. The gas so generated can be burned, with proper nozzles and air supply, in heating furnaces. Annealing furnaces are operated very satisfactorily with 130 B.t.u. gas, a bright cherry red temperature being maintained in the fire. Case hardening furnaces and malleable iron converters can be operated with this gas.

If producer gas were used for heating systems the efficiency

would be at least as great as that of a boiler outfit using coal direct, and, by judicious placing of the nozzles, local strains could be avoided in the boiler, as the heat can be applied wherever desired. No smoke would be formed owing to complete combustion, and in annealing and case-hardening furnaces temperatures can be gaged much more accurately with a gas than with a coal fire, the heat being more steady and reliable. This paper, however, is supposed to be confined to the application of producers for power, and I will not discuss the other uses further.

Practically the only means of using gas to generate power which has so far been developed has been a reciprocating engine. There are certain uses, such as the raising and lowering of railway gates, which have been successfully worked out by the use of a direct-acting piston and having no rotary parts or fly-wheel; but these are only special cases.

The rotary gas engine, as well as the gas turbine, has been receiving some considerable attention from engineers, but, as far as the rotary gas engine goes, there seems no reason to believe that it will be any more satisfactory than the rotary steam engine, which has never yet come up to commercial requirements.

It is too early as yet to make any broad statement regarding the gas turbine, as means may be found by which the excessive temperatures may be taken care of.

However, our present means of converting gas into power is the reciprocating gas engine. There are, of course, many devices and a large number of designs for such machines which we will discuss later. The reciprocating gas engine is confined within rather narrow limits as regards speed ranges; more than 50 per cent. variation of the speed of a gas engine does not seem to be possible; therefore, in the application of the reciprocating engine to power drives this fact is a primary consideration which is borne in mind.

Power systems may be divided into two classes: Those which can be put into motion without load, and those which must start into motion against the full resistance of the load.

It will be seen that the first class is more applicable to gas engines than the second, as it means that the drive can be a solid connection to the engine shaft and the engine still be started, the usual means for starting the engine being by compressed air and the engine not developing its full power until up to speed. With the second class of drive, the only means of connecting the engine to the drive is through a friction clutch or its equivalent. This latter class of mechanism has always been a

source of trouble, and is certainly not so reliable as the solid connection.

To the first class belong certain types of factory drives, electric generators, centrifugal pumps; while to the second class belong plunger pumps, air compressors, hoisting engines and certain other factory drives.

As a general rule, then, it will be seen that there is sometimes a choice between the two classes of machinery for connecting to the engine. It is usually better to use an apparatus from which the load can be removed and which can be direct connected to the gas engine, the load being applied later. There are cases, however, where this is impossible and, in such cases, it is necessary to use friction clutches; the only comfort in doing so is that while a friction clutch is bad, the great saving made by using a combustion engine over any other type of prime mover offsets the disadvantage.

For factory drive work, in case the machines in the factory can be thrown off from the line shaft, the gas engine can be direct connected to the line shaft without clutch, as the engine should have fly-wheel enough to get over the first cycle when starting the shaft in motion. Where the load cannot be disconnected or thrown off from the line shaft, it is necessary to use a friction clutch.

Electric generators and centrifugal pumps can be driven direct or by belt from the engine without clutches, and these two pieces of apparatus are coming to be used very widely for connection to a gas engine.

Plunger pumps, air compressors and hoists must, of necessity, be coupled with friction clutches to the engine, although even with these a proper by-pass arrangement can sometimes be made by which pump or compressor can be started without load.

Figure 7 shows a direct-connected electric generator plant with twinned, single-acting, four-cycle engines. Figure 8 shows a direct-connected plunger pump plant for water-works service. Figure 9 shows a factory drive plant.

I regret that I have been unable to obtain a photograph showing a compressor plant, but will say that with air-compressors the speeds now available in this type of machine will allow of direct connection between the compressor shaft and the gas engine shaft. The writer had the pleasure of seeing a compressor of 150 h.p. running at 600 rev. per min., against 1 200 lb. pressure, operating with the greatest smoothness. It will

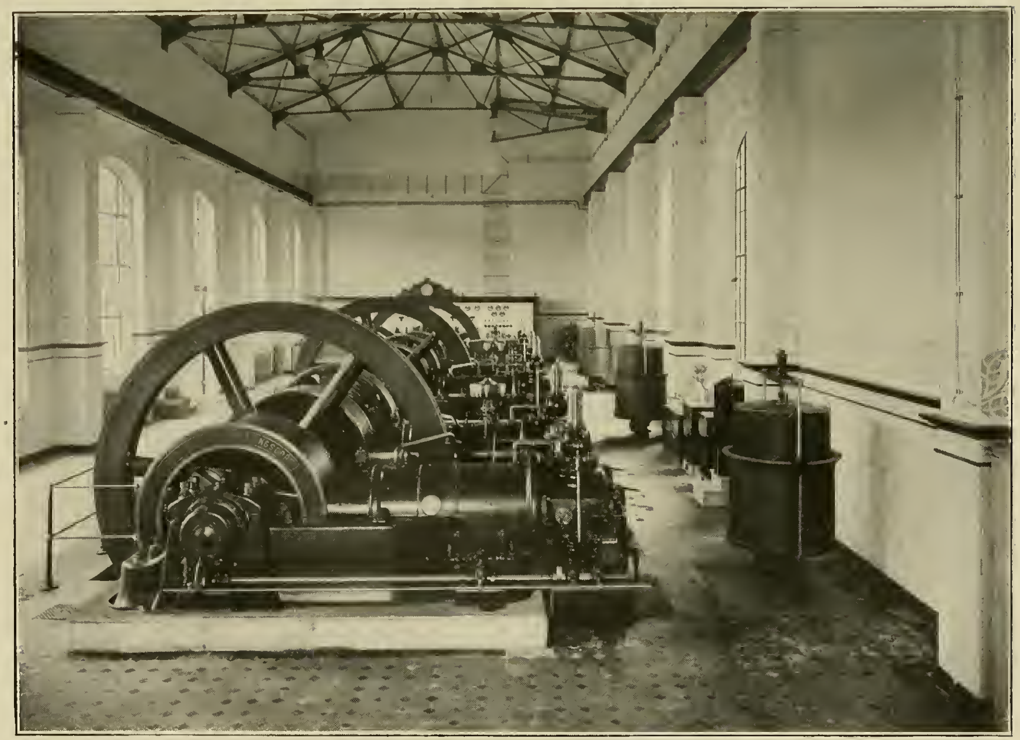

FIG. 7. ENGINE ROOM. (650 H. P.)
Direct-Connected Electric Generator Plant with Twinned, Single-Acting, Four-Cycle Engines.

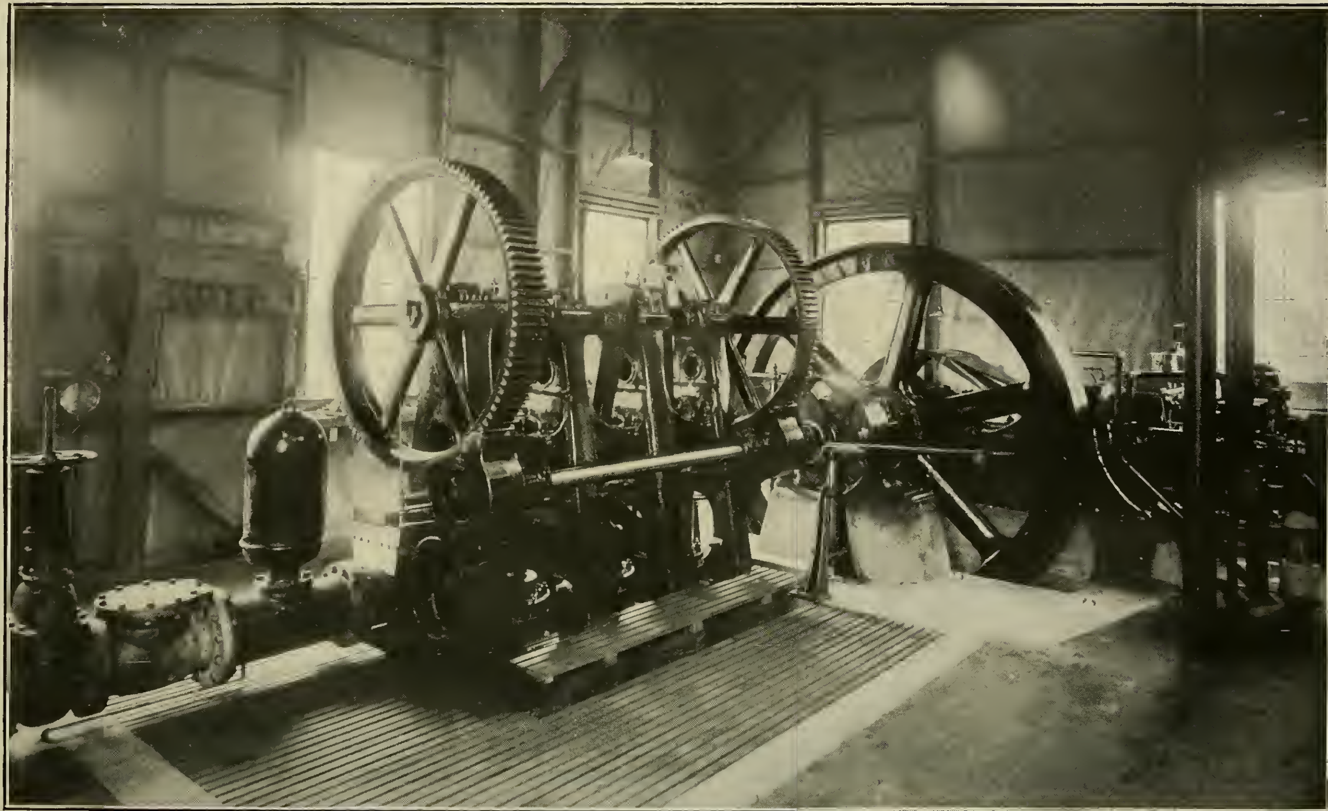

FIG. 8. DIRECT-CONNECTED PLUNGER PUMP PLANT FOR WATER-WORKS SERVICE.

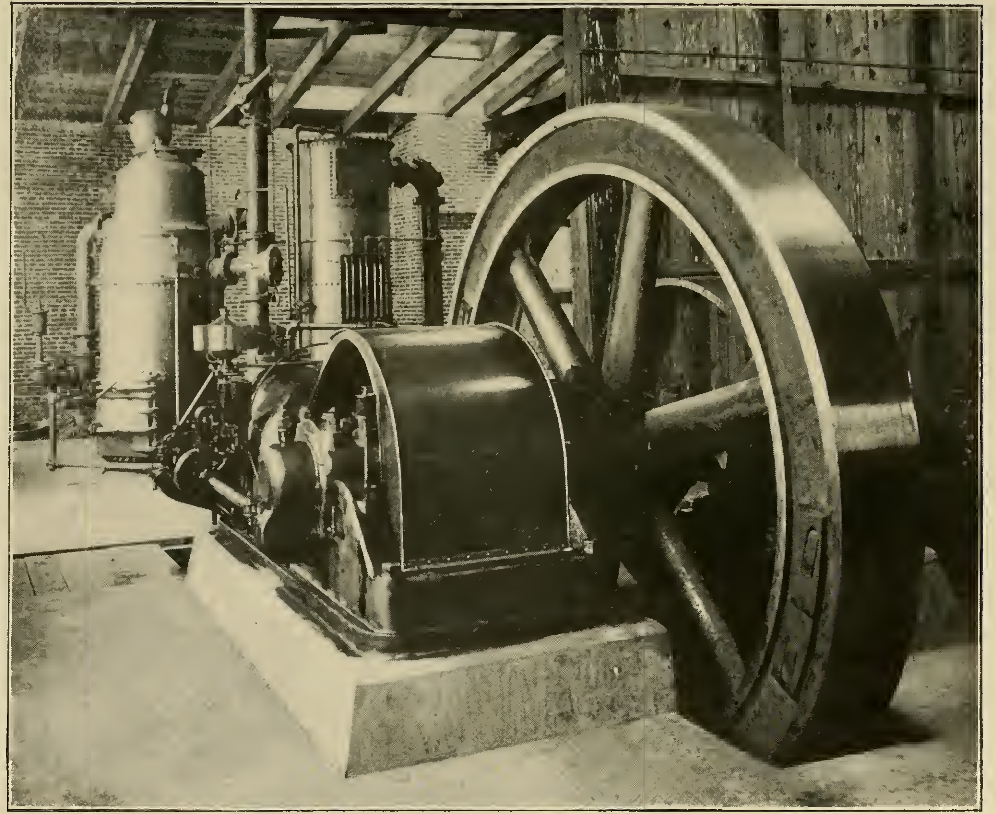

Fig. 9. Factory Drive Plant. Olds 65 H.-P. Engine and Producer, Pottsdown, Pa.

thus be seen that compressors are available for direct connection to gas engines.

The compressors mentioned above are used by the United States government on many of their battleships.

As regards performance of plants, the best gas engine records show that a brake horse-power hour can be developed for 9 100 B.t.u. of heat value in the gas. This was a test on a 125 h.p. Koerting four-cycle engine with illuminating gas of about 600 B.t.u. per cu.ft. With the leaner gases, such as producer gas of about 135 B.t.u., one brake horse-power hour has been developed for 10 000 B.t.u., this with a 500 h.p. Oechelhæuser engine. A 60 h.p. Anhalt engine got off with 10 250 B.t.u. per brake horse-power hour. A Premier engine with 135 B.t.u. gas used 9 100 B.t.u. per brake horse-power hour.

It will thus be seen that with the leaner gases the efficiency is slightly less than with the richer gases and that the size of the engine does not affect the efficiency except in a slight degree. This is a point which affects very radically the design of gas power stations, making it advisable, in most cases, to use smaller units and more of them.

The efficiency of suction producers will average about 80 per cent., and by figuring back from the heat value required per brake horse-power hour at 9 100 B.t.u. in the gas will mean 11 370 B.t.u. required in the coal per brake horse-power hour, which seems to be about the best performance with producer engines. An average pound of coal will have 12 500 B.t.u.; the fuel consumption, therefore, will be equivalent to 0.91 lb. per brake horse-power hour with the Premier engine. The test of this engine was made some years ago and since that time the art has been developed, so that practically any producer engine will develop this efficiency at the present time. A general trade saying is that "a brake horse-power hour can be developed for a pound of coal"; this is at full load.

What one wishes to know is: How much coal is needed to operate a plant under actual conditions? Therefore the best figures for comparison are performances extending over a year's time, all charges to be included. These figures are naturally rather difficult to obtain. These values are expressed in different terms for the different classes of service, but they will be intelligible to those who are interested and can be figured back into pounds of coal per horse-power hour.

These figures include all fuel charges for a year.

Water Works. Triplex-Geared Pumps.

Ordinary water works heads, 100 lb. of pea anthracite coal will develop 125 000 000 ft. lb. of work in water delivered.

(Running 10 hr.; banked 14.)

Water Works. Centrifugal Pumps.

One hundred pounds of pea anthracite coal will deliver 100 000 000 ft. lb. of work in water delivered.

(Running 10 hr.; banked 14.)

Electric Lighting Stations.

One kw. can be generated for 2 lb. of pea anthracite coal.

(Running 24 hr. but with varying load.)

Ordinary Factory Drives.

One brake horse-power hour can be delivered for 1.25 lb. of pea anthracite coal.

(Running 10 hr.; banked 14.)

The above figures can be maintained during a year's run under ordinary conditions. Plants are already in existence doing this service; in fact, in certain cases better records are made, but I consider these to be a very fair average for suction producer performance with the different classes of service, and these performances can be made with plants of not over 50 h.p.

The best record of the Milwaukee 18 000 000 gal. triple expansion engine, running 23.72 hr. per day at full speed, is 122 000 000 ft. lb. per 100 lb. coal. The indicated horse-power of this engine was 540. As compared to this, a 50 h.p. producer gas engine, running 24 hr. per day, made a duty of 156 000 000 ft. lb. This triple expansion steam pump, when operated 63 per cent. of the time, developed a duty of 99 043 000 ft. lb. per 100 lb. of coal. The 50 h.p. producer gas engine, when operated 41.5 per cent. of the time, made a duty of 125 000 000 ft. lb. In other words, a producer plant having one tenth of the capacity of the triple expansion steam pumping plant made a duty of approximately 25 per cent. in excess of the latter, both on test and under running conditions. This is comparing the very highest type of steam pumping apparatus with an ordinary producer. It is true that later pumps of the triple expansion type have made duties of as high as 181 000 000 ft. lb., but this is practically the limit for any type of steam apparatus and the pumps are 36 000 000 gal. capacity.

If a producer pumping plant, however, is compared to a steam plant of its own size, it will be found that the yearly duties will certainly not exceed 50 000 000 ft. lb. with a very high grade of small pump, ordinary direct acting pumps going as low as 25 000 000 ft. lb.

The same general proposition holds true for all classes of work, the very smallest producer plants will make practically the same fuel economies as the very largest and highest grades of steam apparatus and, when compared to steam plants of equal size, will consume about one fourth to one sixth of the fuel. A 50 h.p. electric plant, with producers, will make a kilowatt per hour for 2 lb. of coal. A modern steam plant of the largest size requires 4.25 lb. of coal per kw. hr.; a 50 h.p. steam plant will require as high as 15 lb., 10 lb. being the lowest limit under the very best conditions, 15 lb. being required when loads are variable and the plant only operating 10 hr. per day.

It is to be borne in mind that a steam plant operates with bituminous coal and that the present suction producer plant requires anthracite; therefore, depending on the locality, the cost of these coals will vary from points where anthracite is cheaper than bituminous and where it costs three times as much. As a rule, however, pea anthracite coal will cost twice as much as bituminous coal can be procured for. As a general rule, then, it can be said that a producer plant will save half of the cost of fuel as compared with a steam plant using bituminous coal. That is, it uses one fourth of the coal which costs twice as much per pound.

The fixed charges with the two types of plants should be about equal; that is, the percentages should be about the same. Producer plants are usually more expensive than equivalent steam plants; therefore, the fixed charge against a producer plant is greater; this, however, is usually offset by the saving in labor. Up to 300 h.p. one man can operate a producer plant with ease, taking care of both producers and engines; with a steam plant this would require two men. The saving in labor, therefore, offsets any increase in the fixed charges, so there should be a clean saving in the difference in fuel cost.

It is necessary at times to make provision for heating buildings in connection with power plants. In this case a credit occurs to both plants. With a steam plant all of the exhaust steam is used for heating and usually some extra coal during the six months of the year, while with a producer plant the exhaust gases from the engine can be used for the same purpose but will

have to be supplied with fresh gas from the producers to make heat enough. In either case the efficiency of the whole power and heating system amounts to practically the same thing for the six months, as with either system about 60 per cent. of the heat value of the coal can be turned into power and useful heat in the building. This is supposing the boilers to be in good working condition. During the remaining six months of the year, however, a steam plant has to waste its exhaust heat into the air by running non-condensing, and a producer plant, during these months, will make the saving mentioned above of about one half the fuel cost; as this only extends over six months, however, the actual saving, where it is necessary to heat buildings, will be about 25 per cent, or one fourth of the fuel cost.

It will be understood that these figures are rather rough approximations, as each particular case is individual and should be carefully calculated by itself. However, it can be said roughly that where it is not necessary to heat buildings, the only requirement being the generation of power, a producer plant will save half the cost of fuel as compared with a steam plant; and, where it is necessary to heat buildings, it will save one quarter of the cost of fuel as compared with an equivalent steam plant.

A gasoline plant usually requires three times the fuel expense of a producer plant, but fixed charges are enough lower to sometimes make such an outfit available. Water power is, of course, the cheapest but can only be obtained in a few localities, and even then depends upon the flow of water, which is variable and uncertain. Crude oil engines of the Diesel type are doing good work but usually require three to four times the cost of producer gas fuel and the fixed charges are as heavy.

Concerning the best types of producer gas engines, the simplest machine compatible with efficiency and durability is the best; for this reason, on many grades of work, a single cylinder is better than a multiple cylinder machine. For driving pumps, air compressors, most kinds of factory drive work and ordinary store lighting, single cylinder engines will give a steadiness of running which is perfectly admissible. For the finer kinds of electric lighting it is necessary to have at least two cylinders. Especially is this the case with alternating current generators which have to be run in parallel with other machines.

As a matter of choice between vertical and horizontal engines, unless space is so limited as to require a vertical engine, the horizontal is preferable. With this type of engine all of the parts are accessible, pistons can be removed without taking off

the cylinder, the valve gear is within easy reach of the floor where it will receive proper attention. Vertical valves can be used, giving a very small compact combustion space, and the lubrication of the cylinder is absolutely controllable.

A point which has been raised against this type of engine is the wear of the piston on the cylinder. It may be said, in this connection, that the only difference between a vertical and a horizontal cylinder, as regards this point, is that with a horizontal machine the weight of the reciprocating parts comes against the bottom of the cylinder, this not being the case with a vertical engine. It will readily be seen that in an engine in which the reciprocating parts weigh 300 lb., the pressure on the side of the cylinder, due to the pressure on the head of the piston, will amount to seven times this figure. In other words, the weight of the parts is only one seventh of the total pressure on the side of the cylinder and this increase can readily be taken care of by a small increase in the surface of the piston. Moreover, with a horizontal cylinder the cylinder itself can be supported direct from the foundation, which is not the case with a vertical engine where the heavy side thrust of the connecting rod is distorting the cylinder and tending to force it off to one side at each explosion.

The lubrication of a horizontal cylinder is easy, because if a drop of oil is placed on the top of the piston it will run down both sides of the piston to the bottom, covering the entire circumference with lubricant, which is then wiped end-wise the full length of the cylinder by the piston in its travel. In this way every point of the cylinder is lubricated. In a vertical engine no means has yet been devised by which a single drop of oil can be spread over the whole surface. Gas is not like saturated steam in which there is a fine mist of water in turbulent movement and in which a drop of oil upon entering will immediately be torn apart and distributed over the surface of the myriad small particles of water in the steam by capillary action, later being deposited evenly on the inner walls of the cylinder when the steam enters it through the cylinder port.

Gas has no entrained water or vapor which serves to carry and break up this oil; therefore the oil goes in as a drop into the cylinder, being thrown against the opposite wall of the cylinder, where it remains lubricating this side only. In a vertical engine, therefore, it is necessary to use splash lubrication for the cylinder; this means that the cylinder is always over-lubricated, causing ignition troubles by a deposit of oil and

accumulating on the piston head and inner surface of the combustion space, thereby causing pre-ignitions.

The difficulty of spreading oil with any gas which does not contain water was well demonstrated in the days when superheated steam was just beginning to be used for steam engines. Superheated steam, of course, contained no vapor or water to spread the oil and it was found necessary to immediately abandon the old methods of oiling and carry the oil with pipes to every working surface direct to the point where it was to be used, and even at that it was a difficult matter to keep cylinders from cutting, even though the amount of oil was increased many times. It is my opinion that the horizontal engine is better, under any conditions, for producer gas service, the question as to whether one or two cylinders shall be used being answered by the statement that one cylinder should be used wherever possible. without going above 150 h.p. in one cylinder, double cylinders being used only when sizes exceed this amount or when very close regulation is desired, as in parallel alternating current work.

Where two cylinders are used it is better to place a fly wheel between the two cylinders, and if it is not possible to take the work from fly wheel or pulley between the two cylinders, take it off from a tail shaft outside of the unit, as shown in Fig. 7, where it will be seen that the generator is on the far side of the second cylinder, the fly wheel being between the two. By this arrangement the explosion strain is taken directly from the crank of its own engine to the fly wheel, whereas, if the fly wheel were placed outside of the unit the explosion strain of the first engine would have to go through the crank of the second to reach the fly wheel.

For pumping work a single cylinder is satisfactory; there the speed variations do not make any particular difference. Most factory work can be done with a single cylinder, although some of the fine spinning mills require regulation almost equal to alternating parallel work.

The ignition system for producer gas work should be of the make-and-break type and, where absolutely continuous service is desirable, a double ignition system should be used from two independent sources of current.

Compressions for producer engines should be in the neighborhood of 175 lb. per sq. in. as against about 80 lb. with an ordinary illuminating gas engine. This means that the engine must be especially designed and will have a weight of almost

twice as much per h.p. as the average gas engine upon the American market to-day.

All anchorages for fly wheels and parts taking sudden strains should be by double key or some method of increasing the strength of the tie. In fact, the design all the way through on these machines should be with the idea that one is building a gun instead of an engine; if this is carried out trouble with breakages and weakness of parts will not occur.

The problem of plant arrangement is different with a gas engine and with a steam plant. In the first place, owing to the fact that small engines are practically as efficient as large ones, it is best to use small units and more of them, as stated before. The usual plant which has any serious service upon it has at least one relay engine, and if the whole plant can be cut up into several small units the relay engine is a much smaller percentage of the whole plant cost than as though the whole power were in one unit and the relay engine had to be of equal size.

Moreover, the usual power plant to-day has a variable load, the changes going over a wide range, and by having several small units the load can be followed up or down by cutting in or out more machines, thus keeping the remaining machines which are in service operating at nearly full load, which is their economical point.

Of course the best layout for a plant is to have either electric generators, pumps or compressors direct connected to the main engine shaft. This is the most compact station layout that can be made, and the only reason that it is not used universally is because of the considerably greater cost.

A satisfactory layout where a number of machines are to be used is to belt from each engine fly wheel to a jack shaft; from the jack shaft anything can be driven. In this connection it should be said that only the highest grade of jack shaft should be used. The writer has found that the quill type of shaft, in which the strain of the driving belt is carried upon a pulley mounted on a hollow quill which has its own bearings and does not run in contact with the main jack shaft at all, is the most satisfactory. The quill has part of the friction clutch mounted on its end outside of one of its bearings and the other part is mounted on the jack shaft and, therefore, when any engine is standing the jack shaft can rotate without any strain from the driving belt and without being in contact with any standing part. It has never anything to bear except a torsional strain which is perfectly central.

Means should be provided for easy handling of coal and ashes from the producer room although, owing to the small quantity of coal used, this is not a very serious matter.

It may be considered as demonstrated that suction producer gas plants are the most economical of all types for power generation, using the term broadly, but assuming that they are equipped with machinery especially designed for the work. If machines are installed which embody the same sound engineering principles that have been used so successfully in other classes of engineering design, the same practical results in low repair charges, reduced attendance and certainty of operation will follow.

[NOTE.— Discussion of this paper is invited, to be received by Fred. Brooks, 31 Milk Street, Boston, by March 15, 1907, for publication in a subsequent number of the JOURNAL.]

THE MAINTENANCE OF SEWAGE FILTERS IN WINTER.

By George E. Bolling, Member of the Sanitary Section of the Boston Society of Civil Engineers.

[Read before the Sanitary Section of the Society, December 5, 1906.]

The sewage filtration plant at Brockton was first put into commission in November, 1894, and consequently the disposal of the sewage in winter was the first problem encountered there. In preparation for that winter some of the beds were left level and some were furrowed, and in comparing the efficaciousness of the beds left flat with those that were plowed into ridges I can do no better than to quote from the Annual Report for 1894 of Mr. F. Herbert Snow, then city engineer of Brockton, who wrote under the heading, "Effect of Frost on Level Beds":

"Considerable ice began to form early in December, 1894, around the edges of the level beds, and gradually to approach the carriers. The temperature of the sewage, at this time, about 44 degrees fahr., was readily chilled by the snow to a point where it had little power to melt the ice. Observations, made while putting sewage into snow, showed the temperature to be: in the pipe, 45 degrees fahr.; 20 ft. away from the carrier, 43 degrees; 50 ft., 42 degrees; 75 ft., 37 degrees; and beyond this the sewage did not penetrate the snow at all. Within this area the liquid retained in the upper inches of the filter by the accumulated organic matter froze solid. At a greater depth than 2 in., less liquid being retained by the sand grains, though frozen, the mass remained porous. If there had been warmth enough in the applied sewage to thaw the upper layers it would readily have passed through the lower porous, though frozen, sands. But it is easy to understand how the sewage flowing in a thin sheet became chilled by the ice and snow to a point where it could not thaw its way through the upper frozen layer, thus rendering the level beds entirely useless until warmer weather."

After the experience of this first winter, the system was adopted each fall of plowing into ridges all the beds that were intended to be used during the following winter, leaving level only those that were not required in the operation of the plant. Within a few years, however, the increasing volume of sewage demanded the use of these few reserve beds, and so, after about 4 years of operation, the entire complement of 23 beds was furrowed each fall in preparation for the freezing weather to follow.

As first practiced in preparing to furrow a bed, it was first plowed and harrowed, and then furrowed, but it was found on trying the experiment that unless a bed had had considerable heavy teaming done over its surface and the soil was packed down hard, the preliminary plowing and harrowing could be dispensed with, and the flat bed furrowed directly into ridges, thus saving the extra item of expense.

In making the furrows we use a common Ames No. 2 double-moldboard plow, with an extra iron form attached to the moldboard, which enables a deeper cut to be made, and the flaring edges round over the shoulders of the ridges, leaving less loose material to fall or be washed down into the furrows.

At present, the beds are prepared for winter use with the top of the ridges about 3 ft. apart, and the furrows about 12 in. in depth. It is found after a bed is newly furrowed that, for the first four or five doses applied, material from the sides of the ridges will be washed down into the bottom of the furrows, but after the fourth or fifth dose very little is washed down. This washing of the material down into the trenches is of no particular moment except in case of the sludge beds where alternate layers of sludge and sand are deposited, necessitating the removal of considerable of the filtering material when the beds are cleaned in the spring. It is customary with us to dose a newly-furrowed bed that is to receive sludge during the winter with one or two preliminary doses of the lighter sewage, as it is in the first one or two doses that the most of the loose material of the sides of the ridges is washed down into the trench.

The one great object to be accomplished by furrowing a bed for winter use is, of course, to keep the ice which in this latitude is certain to form in an ordinary winter from attaching itself to the whole surface of the filter.

In our experience, frost cannot be kept out of the trenches; in fact in a winter of ordinary severity the frost penetrates down into the bed 8 or 10 in. below the bottom of the trenches. This frost line in a way is comparable with a water table, in that it conforms to the configuration of the surface of the ground, and while almost the entire ridge may be frozen solid and the frost have penetrated down into the bed nearly a foot below the bottom of the trenches, the unfrozen sand under the ridges is nearer the sewage when it is applied than is that directly under the furrow. Therefore, the sewage when flowing in the trenches of a furrowed bed exposes less surface to the cold and has its warmth conserved while thawing through the frost to the more

porous sand. It is our experience that as the strength of our sewage has increased and the amount of sediment deposited in the trenches has become consequently greater, presenting an almost impervious layer to the applied sewage, much of the absorption into the body of the filter takes place diagonally downward through the sides of the ridges.

On the application of a dose of sewage to a furrowed bed in the winter absorption does not take place until the warmth of the sewage has thawed out a way for itself along the path of the least resistance. While this is occurring and there is no settling of the sewage a sheet of ice forms on the top, and when subsidence is finally effected this ice is left supported by the top of the ridges, affording an additional help in conserving the heat of the additional doses applied to the bed.

The foregoing has been our experience with furrowed beds in winter. We never have had a bed that was left level for winter use completely freeze up, so as to be of no use, except in one instance. This was in the case of a sludge bed, from which the sludge was removed so late in the season that when the bed was ready to be furrowed a sudden cold snap made it impossible to work the frozen ground. On attempting the use of this flat bed during the ensuing winter, the first dose froze to the surface of the ground and successive doses merely flowed out on top of the ice and added to its thickness. This, however, was a bed from which, during the construction of the plant, the subsoil had not been removed. The belief that the fact of its being a subsoil bed was responsible for its freezing is strengthened by our experience with Bed 23 in the winter of 1903–1904. This is a bed from which the subsoil had been completely removed at time of construction, and which for the winter of 1903–1904 was left level.

In November, four doses, averaging 112 000 gal. each, were applied, the average time of absorption being 60 min. In December but one dose of 112 000 gal. was applied; this required 3 hr. for absorption. The mean temperature for this month was 28 degrees above, and the minimum 5 degrees below zero. In January there were three doses applied of 250 000 gal. each, and the time of absorption averaged 20 hr. The mean temperature for this month was 21 degrees, while the extremely low minimum of 33 degrees below zero was recorded at the filter beds on the night of January 4.

In February, but one small dose of 50 000 gal. was applied, this being absorbed over night. The mean temperature of the

month was 14 degrees above, and the lowest, 3 degrees below zero.

In March fifteen doses of 180 000 gal. each were applied, being absorbed in the average time of 8 hr. Mean temperature of the month was 35 degrees and the lowest 6 degrees above zero. In the first week of April and once again in the second week, a slight clogging of the surface of the bed was remedied by going over with a one-horse spring-weeder, and the bed was continued in use on alternate days until it was cleaned and plowed in the first week of June.

The bed continued to yield a good (for winter) effluent during this period; the analysis of a sample collected March 30, 1904, being as follows, in parts per 100 000:

Free Am.	Alb. Am.	Chlorine.	Nitrates.	Nitrites.	O. Cons.
1.3040	0.0700	6.32	0.450	0.0170	0.75

Compared with the applied sewage, the purification effected is shown by the removal of 75 per cent. of the free ammonia, 97 per cent. of the albuminoid ammonia and 97 per cent. of the oxygen consumed; and this on a level bed during the most severe winter on record for years.

If asked what was the nature of the material composing this particular bed and the effective size and coefficient of uniformity, I should be stumped for an answer, as about any kind of material one could desire is to be found in that bed. In one test pit, 5 ft. in depth, I have observed and collected samples from nine different strata varying from a coarse porous gravel to a hard clay. In February, 1904, frost was found to have penetrated to a depth of 20 in. into the filter. This bed was underdrained at a depth of 6 ft.

This same winter of 1903–1904 was the most disturbing one to our peace of mind since the plant has been in operation. The long-continued low temperatures in January caused the formation of ice in the bottom of the trenches in nearly all of the beds. It was not over the entire area, but started first around the sides by freezing the sediment remaining in the furrows, and then the whole section of the furrow itself filled with ice as successive doses were applied, until in some cases a third of the bed was frozen solid and unavailable for filtration purposes, the rest of the bed simply being put to it to do the work of the whole area.* The worst bed was Bed 1, a sludge bed, in which the ice increased

* In an ordinarily severe winter the ice on the beds would vary from .5 in. to 6 in. in thickness.

to a thickness of 40 in., and only about one half of the bed was available for absorption of the sewage. One of the laborers was so impressed by the glacier-like expanse of ice in sight on this bed that he ventured the opinion that it would be a nice, cool place to come and sit in the hot days of the following summer, as he couldn't see how all the ice he then beheld could possibly melt in the short space of a few months. The ice on this bed hardly lingered long enough to give us a little trouble when it was cleaned in the second and third weeks of April.

For about 8 years in the operation of the plant the application of sewage to furrowed beds during the winter months was followed by the proper subsidence of the sewage, within a period of from 4 to 48 hr., leaving a dry bed ready for the next dose. After this time the gradually increasing amount of organic matter in the upper 6 to 8 in. of the beds had reached a point where in both the sides of the ridges and in the bottoms of the trenches a clogging occurred that would not permit the absorption of the sewage until such a depth was put on to the bed as provided a sufficient head to force the sewage through the clogging material. When sewage was applied to a bed it would gradually increase in depth from 0.5 to 1 ft. above the top of the ridges, at which point a head sufficient to force absorption was attained.

It may be thought that considerable deterioration in the quality of the effluent would be apparent about this time, but such was not the case, as the winter effluent from any of the plants in this region treating sewage at all approximating the strength of Brockton's sewage is none too good. A view of the plant at the time of the spring thaw would lead the uninitiated to believe that all the water coming to us during the whole winter past was piled up on the beds, until a little calculation would show that if such were the case the beds instead of being covered with 12 to 18 in. of sewage would be inundated by from 25 to 30 ft. of it. It was necessary during a few successive spring cleanings in order to get at the surface of the beds to facilitate the absorption of this supernatant sewage by going over the clogging material of the surface with rakes. This was necessary in order that it might be absorbed before the increasing warmth of the spring produced a nuisance. In the winter, of course, no odor from the beds was noticeable. This raking over in the spring to hasten absorption would cost from $3 to $10 per bed, and occasionally a particularly obstinate bed would cost $20. This cost has been largely eliminated the last few years by trying

the scheme of cleaning one or two of the lower elevation beds before the others, levelling them flat and then, by means of pipes laid through the low embankments, drawing off the supernatant sewage of the other beds on to those freshly prepared, where it was readily absorbed.

An especially good feature of the seven additional filter beds added to our plant in 1905 is that they average 8 ft. lower in elevation than our old beds, so that in the spring, when the supernatant sewage on the old beds is at its greatest height, it is drawn down on to three of the beds of the new plant by means of a specially constructed masonry chamber.

To be ready for this purpose in the spring these three new beds are left level during the winter, and it was our intention during last winter, which was the first time of its trial, not to use them at all for the disposal of sewage during the winter months. But the continued mild weather induced us to keep up their use during the winter months, so that it is possible to give a few comparisons on the use of three furrowed and four level beds during their first winter's service, bearing in mind, however, the fact of its being a very open winter.

Beds 24, 25, 28 and 30 were left level and Beds 26, 27 and 29 were furrowed; all were dosed on an average every third day, and once in a while every second day during the months of December, January and February, each bed having 35 doses during the three months, the size of the dose being the same in all cases, about 135 000 gal. per acre. Each bed dried after each dose it received, the flat beds averaging 7 hr. for absorption, and the furrowed beds 8 hr.

These 3 months are selected as they were the coldest months of the season, but the beds were continued in use throughout March and April, until they were cleaned early in May. The amount scraped from the level beds averaged 246 loads per acre, while from the furrowed beds 375 loads per acre were removed.

Observations extending back during a period of 10 years show the average coldest temperature of the sewage during the year to be 43.8 degrees, occurring in the month of March. The average coldest temperature of the effluent in the same period of time was 40.4 degrees, also occurring in March.

In the summer of 1905, as the beds continued to become slower in absorbing sewage, an attempt was made to remedy this by removing from 19 beds 6 in. of the surface material. In all about 16 400 cu.yd. were removed at a total cost of $4 314.36.

This material removed varied in amount of organic matter, as shown by the "loss on ignition" from 0.7 to 4 per cent. by weight. It varied in "organic nitrogen" from 90 to 280 parts per 100 000 parts.

This removal quickened the absorption of the beds thus treated during the remainder of that summer, and also during this summer, but in the winter of 1905–1906, the same tendency of the sewage to pile upon the beds was observed. As our sewage has steadily increased in strength, and, consequently, in amount of sediment deposited in the furrows per dose of sewage, it is believed that the slower absorption of last winter is in part due to this factor. Prior to 1896 we have no data regarding the strength of the sewage treated; the plant was performing in 1905 just twelve times the amount of work imposed upon it 9 years previously, in 1896.

For purposes of comparison of the increasing amount of work accomplished by the plant in Brockton we obtain what we term an albuminoid factor by multiplying the yearly average of the albuminoid ammonia of the sewage for the respective years by the number of hundred million gallons of sewage treated during those years. This factor being obtained, its comparison with that of any other year shows at a glance the ratio of one to the other in work imposed upon the disposal plant.

This accumulation of the sewage upon the beds in winter in Brockton has not worked to any permanent disadvantage. The analysis of the effluent from these beds differs but little from what it was when the beds used to become completely dry between doses. To show that no permanent injury is done, the following typical analyses are given:

On April 20, 1906, when the effluent of Bed 12 was at its very worst, it presented in parts per 100 000:

Free Am.	Alb. Am.	Chlorine.	Nitrates.	Nitrites.	O. Cons.	Bacteria per cu.cm.
3.1580	0.2600	7.95	0.000	0.0000	3.96	4 400 000

representing a purification as indicated by the amounts of free ammonia, albuminoid ammonia and oxygen consumed removed of 51 per cent., 91 per cent. and 69 per cent. respectively, and a bacterial purification of 66 per cent., the bacteria per cu.cm. in the sewage at that time numbering 11 000 000. On September 28 the same bed which had received but the customary attention in going over the surface and in scheme of dosing during the summer, gave an effluent which analyzed as follows:

Free Am.	Alb. Am.	Chlorine.	Nitrates.	Nitrites.	O. Cons.	Bacteria per cu.cm.
0.0120	0.0150	16.90	4.00	0.0028	0.37	216

representing a purification as shown by the amounts of free ammonia, albuminoid ammonia and oxygen consumed removed of 99.8 per cent., 99.5 per cent. and 97 per cent. respectively, and a bacterial purification of 99.99 + per cent.

Many of the winter effluents, while appearing only slightly turbid at time of collection, after standing in the laboratory a short time begin to deposit a copious precipitate of iron which renders them very unsightly. This iron is derived from the soil of the filter beds and its solution in the effluent is facilitated by the amount of organic matter the winter effluents contain. Effluents carrying as much iron as 12 parts per 100 000 parts are not uncommon in the winter. The quality of the effluent improving as the summer advances, the iron gradually grows less in amount and finally ceases to be apparent.

It may be asked why, if this standing of sewage to á depth of, in some cases, 18 in. upon the beds is to be a regular occurrence each winter, is there any advantage in furrowing the beds at all. We believe that, if it were not done and continued cold weather should ensue before the sewage had reached its winter height, there would be a possibility of ice forming and attaching itself to the entire surface of the bed which would then, of course, throw the bed out of use for the rest of the winter.

As regards the relative cost of having the filters furrowed and leaving them level, there is not much to choose between the two.

The average cost of furrowing a bed is $3.30, and of shovelling the outlets from the carrier through the ridges so as to permit the distribution of the sewage over the bed is $1.91, a total of $5.21.

If the bed were left level for winter use we should consider it advisable to first plow and harrow it on account of the amount of teaming done over it during the summer; this would cost $4.17 for plowing and $1.02 for harrowing, a total of $5.19.

The item where expense might be saved is the greater ease in cleaning a flat bed. The average number of loads of sediment and dirty sand removed from a furrowed bed in the spring is from 200 to 400. On a flat bed this sediment could be gathered up without taking anything like as much of the filter material with it.

But here the question presents itself: Is not the furrowed

bed all the better off on account of having so much of the material with a tendency to clog removed from it?

DISCUSSION.

Mr. E. R. B. Allardice. — The Clinton sewage disposal plant was built and is maintained by the Metropolitan Water and Sewage Board. It comprises eight settling tanks and about 25 acres of filtering area, divided into beds of about 1 acre each. In the fall of the year, just previous to the time when freezing takes place, 5 of these 25 beds are furrowed. The sewage is delivered to these beds from an inlet which is placed at the middle of one side, and to carry the sewage directly across the bed three main channels are dug, which divide the bed into four equal parts. Then at right angles to these three main channels there are furrows similar to those described by Mr. Bolling, the furrows being 3.5 ft. apart and 15 in. deep. Previous to this work in the fall the bed is given a complete cleaning by raking up any scum or sediment which has formed on the surface during the summer. The sewage is applied to the furrowed beds at such times as the temperature at 7 o'clock in the morning is below 15 degrees fahr. When the temperature is higher the flat beds operate satisfactorily.

The furrowed beds are given doses which range from 500 000 gal. per acre upwards. The dose is sufficient to flood the bed to a depth of more than a foot above the ridges, and, before it has seeped away, a coating of ice some 2 in. in thickness has formed, so that when the sewage has entirely disappeared this rests on the tops of the furrows, thus protecting the bottom, which we find has never become frozen, always being soft and ready to carry away the sewage at the time of the next application. When the temperature is higher than 15 degrees fahr. we apply the sewage to flat beds in doses of 250 000 gal. per acre. This we find can be done at all times, unless there is deep snow on the bed. At these times we plow furrows in the snow, about 10 ft. apart, thus allowing the sewage to reach the far points as quickly as possible. But, unfortunately, this method of applying sewage has not been entirely satisfactory, the sewage becoming so chilled that a heavy coating of ice forms on the beds, and unless we have a few days of moderate weather the bed will be forced out of commission.

In the spring of the year, when the freezing weather has passed by, we find that there is sediment in the bottom of the furrows from 4 to 6 in. deep, and this has to be cleaned out and

carted off. We usually get from 275 to 300 loads from each bed. The quantity of solid matter has been greatly reduced by passing the sewage through settling tanks, which were built in the fall of 1904. The sewage is allowed to pass through one tank for two weeks at a time, and since they have been put in operation, which was only last year, we have not been compelled to clean the bottom of the furrows in the spring, the settling tanks taking care of almost all of the sludge which was in the sewage.

Mr. E. C. Frost. — Many reports have been made public explaining the methods employed in preparing the filter beds at Framingham, therefore it would avail nothing to describe them in detail here. Suffice it to say that the loam was removed, the beds graded, the cuts making the fill in many places, and in no instance was a filter wholly made of foreign material.

From the foregoing we can understand why it is that no two beds at Framingham are of the same character and they, therefore, cannot be treated the same, some being of much looser material than others and differently drained; therefore, we can have no fixed rule for flooding our beds unless it be "moderation" and "eternal vigilance."

We prepare the filters each spring by raking and removing sludge, plowing, and planting Indian corn in hills 3 ft. apart each way. A hill about 5 in. high is made around the stocks, which are cut each fall about 5 in. higher than the surface of the hill.

In flooding beds in winter I consider it one of the vital points to cover them quickly and to a greater depth than in summer. My reason for so doing is that, provided freezing weather prevails, the ice forms well up on the hills and there rests until melted away by warm rains which, of course, puts your filter in good condition again. Should the weather continue cold, be sure to flood the bed as quickly as possible, thereby melting a larger amount of ice than would be melted by running slowly. In this way the bed can be kept open a much longer time. The above method is carried out if we have a fall of snow when no ice protects the surface of the filter and for the same reasons.

A great mistake can be made if one should try to keep open too much filtering surface with a given amount of sewage during a continued "cold snap." After having learned the amount of sewage each bed is capable of handling satisfactorily it is then easy to determine how many beds are required to filter your supply, but a mistake can also be made by not starting with

enough. I always prefer to start with more than enough and keep as many of them in good working order as possible, and if I get a few warm days I always open up another filter or two, perhaps resting some that have had all they can do for a long time. Ordinarily there are sufficient warm spells or "thaws" during each winter of sufficient duration to enable me to open up others, so that practically all of our filters get their share.

Mr. L. M. Hastings. — What is done with the sludge taken out of the furrows at Brockton? Is there any difficulty in disposing of this large amount of sludge?

Mr. Bolling. — No, we have no difficulty. Last year we removed about 4 000 tons. Previously to that year we had sold the whole output to one farmer, who sold it in smaller quantities to others. We sold it to him for the sum of $150. Selling it obviated the necessity of cremating it, and he was responsible for taking it away as soon as we removed it from the beds. He had no trouble in getting the people to take it. This year we stopped charging him for it, but he promised to take it away just the same. He sells it for 25 cents a load, and there is about a ton in a load.

Mr. Hastings. — What is done with the sludge in Clinton?

Mr. Allardice. — Our sludge is so mixed with sand and gravel which fall into the furrows that we find it hard work to dispose of it to the farmers, and we carry it off and put it in the dump. The sludge we get in the sludge tanks we give to the farmers and find a very ready market for it. We rake it up into piles in the tanks and the farmers cart it off.

Mr. Hastings. — Is that done at the end of the season?

Mr. Allardice. — It is done during the whole season except, of course, in the winter, when it is frozen.

Mr. R. S. Weston. — I think it would be well at this point if some one would tell us briefly what the analytical character of the sewage in these places is. As I understand it myself, the sewage at Brockton is domestic, mixed with a very little shoe manufacturing waste. The sewage at Clinton is a textile waste, mixed with domestic sewage, and the sewages at Concord and Framingham are almost purely domestic. Perhaps Mr. Johnson could tell us about that.

Mr. W. S. Johnson. — The sewage at Brockton is a very strong domestic sewage containing some wastes from shoe factories. The sewage at Clinton contains a large quantity of wool scouring wastes. At Framingham spent dyes from the straw factories and from the Dennison Manufacturing Company

are discharged into the sewers, giving the sewage a distinct color. Sometimes the effluent from the Framingham filter beds is a bright red, at other times it is a brilliant green. The Concord sewage is strictly domestic.

Mr. L. Metcalf. — One question occurs to me which I should like to ask Mr. Bolling. Has any comparison been made of the cost of constructing and maintaining spare beds for use in draining the other beds in spring, having them idle during the winter, as compared with the cost of treating the beds without them? You said it was cheaper to drain off the beds on spare beds. I wondered if you had figured in the additional cost of building and maintaining those beds?

Mr. Bolling. — It is cheaper to do it in this way. On some of the beds the sewage reaches a depth of 18 in., and in the spring it would be practically impossible to get that absorbed into the bed; it would cost a large sum to rake it over until it was absorbed, and this would have to be done, because it would otherwise become a nuisance when the weather got warm. So we find that the best method is to draw it off on to fresh beds, where it is readily absorbed. Also, thus far, since the scheme was inaugurated we have succeeded in making considerable use of these beds during the winter months, even though they were left flat.

Mr. G. A. Carpenter. — Is the sludge at the Brockton plant turned on any special bed in the winter, or on the beds indiscriminately?

Mr. Bolling. — We have five or six beds that we use for sludge beds all the year round. These beds are cleaned five times during the year, but not during the winter. Sometimes the furrows in the sludge beds contain 10 in. of sludge in the spring.

Mr. Carpenter. — How do you get rid of the sludge in the spring? It won't dry out.

Mr. Bolling. — It holds from 40 to 45 per cent. of water, but there is no difficulty in getting it out of the bed.

Mr. H. P. Eddy. — I have said so much on these subjects that I hesitate to get up again. We don't use the furrowed bed, consequently I am a little bit out of joint with the sentiment of the meeting, I suppose. The reason we don't use the furrowed bed is because, in the first place, it costs something to furrow it. In the second place, running the crude sewage on, as we do, without any removal of suspended matter, except that taken out in the grit chamber, 0.3 cu.yd. per million gal., would give

an immense accumulation of sludge in the furrows and put the bed out of business. In the spring, when we clean the bed, it costs a great deal more to get the sludge out of the furrows than it would to remove it from the flat bed. In the third place, every time the surface of the bed is disturbed it mixes the organic matter which is in the sand and is not completely removed in cleaning with the comparatively clean sand below. I appreciate that all of these reasons are subject to discussion and differences of opinion, but my judgment is that the reason we have differences of opinion is largely because of differences in local conditions. We get, as a rule, more water through our filters in winter than in summer, which is another point on which we do not all agree, perhaps. But my impression is that the reason for that in our case is that we do not allow the frost to form to any great depth; perhaps 6 in. would be our limit, and that has certainly the effect of expanding the surface. The frost pushes the grains of sand on the surface, which are mixed more or less with organic matter, further apart and this lets the water through more easily. When the temperature is such that the surface of the bed is just frozen hard enough to drive a team on, without cutting through, the bed is very porous and will take a very large amount of water, and we usually avail ourselves of that opportunity to give it a pretty good-sized dose, 300 000 gal., I should say, to the acre, and in that way get rid of all the frost, and if there is an accumulation of snow, we get rid of that, or most of it, in one or two days. This disposes of the trouble from frost in the bed, which I classify as a different disease from the trouble with ice. The ice which forms on the surface of the bed, before the water penetrates through the sand, settles down, of course, as the water goes into the filter, and if there are no furrows to hold it up there is a tendency for it to freeze to the surface of the bed. To prevent this we rake the sludge on the surface of the beds into piles in the fall of the year, piles, I should say, about 6 in. high and approximately 12 in. in diameter and about 8 ft. from center to center. These piles serve to hold this layer of ice off the sand and to prevent it from freezing on to the surface of the bed, and with that assistance we have had practically no trouble from the ice freezing to the surface of the beds on those beds where sewage is distributed from four different points. This, I think, is a very important point to be considered in designing a filtering plant, to deliver the sewage from at least four points, and at the same time not so many points that it is delivered slowly and cools rapidly. The question of keeping

the bed free from the suspended matter of the sewage in the winter time is a somewhat troublesome problem, and that we deal with by putting a force of men at work just the minute there is an opportunity — that is, just the minute the weather conditions are right. We are favorably situated in this respect by having a force of men near by on another part of the work, and we simply shut down our filter-pressing plant and send the men down there for perhaps a couple of hours in the day, and in that way we are able to rake up the coarse material at such points as may be necessary almost every winter. That enables us to keep our filter fairly open and in good condition. These piles grow in the winter time due to that cleaning, so that in the spring we have 300 cu.yd. of material per acre to remove from the filters.

A MEMBER. — What do you do with it?

MR. EDDY. — We give the neighbors all they will take. Most of them are homeopaths and do not seem to take very large doses. All told, including sludge from chemical treatment, we get rid of from 3 000 to 5 000 cu.yd. a year. The rest of it, which amounts to about 35 000 cu.yd. more, we use for filling up low land and holes anywhere we can find them.

A MEMBER. — May I inquire of Mr. Eddy whether there is not considerable acid in the Worcester sewage?

MR. EDDY. — Well, there is a little sewage in the acid. The chairman has asked about descriptions of sewage. It occurred to me that a description of the sewage of Worcester would be brewery waste, shoddy mill waste, dye plant waste, a good deal of wool scouring, pickling liquids and acids, with a little sewage mixed in.

A MEMBER. — How about the color of the effluent, Mr. Eddy?

MR. EDDY. — Why, the coloring matter in the sewage is removed almost always by the filters, so that the water, as you see it flowing along is substantially free from any of the color of the dyes which were in it originally. In this connection I might state that the iron in the sewage comes through the filters somewhat changed, and, depending somewhat upon the condition of the filters, we get effluents containing almost no iron and effluents which are fairly loaded with the heavy red precipitate of oxide of iron, which, of course, affects the color. But only when the filter is very free, due to frost in the upper layer in the winter and to thorough cleaning in the summer, does the coloring matter in the original sewage pass through the filter without being removed. This is a very unusual occurrence.

A Member. — I should like to ask Mr. Johnson if he has any explanation for the presence of the coloring matter which comes through the Framingham filter. As I understand it, the effluent there is considerably colored by dyes.

Mr. Johnson. — I have no explanation to offer. It is possibly due to the nature of the dyes in the sewage.

The Chairman. — I wonder if Mr. Woodfall will inform us about the operation of the plant at Gardner.

Mr. Woodfall. — At Gardner the beds are furrowed. I think the work is done very much as it is at Brockton. The furrows are made across the bed, and connected by cross-ditches. The ice rests on the ridges and little trouble has been experienced in freezing weather. In 1891, when the beds were first put in operation, they were not furrowed and considerable trouble was given by the ice freezing to the surface of the beds. At the plant in Andover which I constructed, corn is planted in the summer and when it is cut in the fall, the hills are left, and, as far as I am informed, it has given the least trouble of any plant I know of. In conversation with the superintendent three or four years ago, he told me that the beds had been raked or cleaned but once and then it was necessary only on account of flushing out the long inverted siphon through which the sewage passes on its way to the filter beds. As I understand it, the effluent is not as good as in a great many other places. I think, possibly, that Mr. Johnson might give a few points if he cared to. He is, perhaps, more familiar with present conditions than I am.

Mr. Johnson. — I think the explanation of the fact that so little cleaning of the beds is necessary at Andover is that the solid matters are almost entirely removed from the sewage before it reaches the beds. In the first place, there is a septic action in the long siphon of which Mr. Woodfall has spoken, and then the sewage passes through a settling tank of considerable size as compared with the flow, which very effectually removes the solid matter. The sewage when discharged on the beds contains little solid matter and what it does contain is very finely divided; consequently, the beds never need raking, but a very poor effluent is produced.

A Member. — I should like to ask Mr. Johnson if he has any explanation as to why the effluent is so poor.

Mr. Johnson. — The experience in this state has been that septic sewage gives a very poor effluent. At Hopedale, Gardner and Andover, where septic sewage is applied to filter beds, the

purification is less complete than in those places where fresh sewage is applied. The purification would probably be better if the septic sewage were aërated, but under the conditions as they exist in Massachusetts the poorest effluents are obtained from filtering septic sewage.

Mr. Leonard Metcalf. — With reference to the Hopedale situation, I should like to ask Mr. Johnson, May it not be in part from the fact that the beds there are very shallow, that the effluent is so poor? He will recollect that when the beds were first constructed we were fooled completely by the character of the soil. We dug a large number of test pits considering the area of the beds, and took samples of the sand, which showed a free material, a suitable material for use. But when we came to make the excavations we found the area was a regular stone quarry, and it became necessary later on to cart material on to these beds. I have always had the feeling that upon the upper beds the work was being done by from 18 in. to 2 ft. of material. But, so far as I know, and Mr. Johnson will correct me if I am misstating the fact, we have had no comparative analyses of the effluent from different beds at that plant. I think it might be interesting to see whether or not there is any difference in the effluents from the different beds on account of the fact that the lower ones are of greater depth.

In the Hopedale plant the carting of sand on to the beds was viewed as a pure question of dollars and cents. We did not go any further in putting on suitable material than we felt we had to in order to secure satisfactory results.

Mr. Woodfall. — In the Andover plant the sub-drains were put usually at the depth of from 4 to 5 ft., and in some cases deeper. Perhaps half the area was underlaid with gravel which was not disturbed at all. Trenches were simply cut through the beds and the pipes laid in them. The other half was artificially made from material taken from a higher level. This, I think, will corroborate what Mr. Johnson says, that if you carry the septic action too far it makes no difference whether your bed is deep or shallow; you are likely to have imperfectly purified effluents.

Mr. C.-E. A. Winslow. — I should like to say that the experiments we have made at the Technology Experiment Station strikingly corroborate Mr. Johnson's observations on this point. We have, for a period of about a year, filtered crude Boston sewage and septic effluent on sand filters under strictly comparable conditions and have found that the effluent from

the combined septic and sand process is uniformly poorer than that from the sand process alone. The two filters were operated at the same rate and the surface of that which took septic effluent was somewhat easier to care for than that which took crude sewage, although the difference was not marked. On one occasion the septic effluent clogged the filter very rapidly by a deposit of finely divided sulphide of iron, as we supposed. It was evident at all times that without some special preliminary process of aëration the septic treatment produced an effluent which would not nitrify readily.

There is one other point to which I should like to call attention which has not been brought up in this discussion; that is the variation in the chemical composition of the effluent at different seasons. No doubt the most important effect of winter is that upon which the speakers have dwelt, the clogging of the filters, with the consequent practical difficulties in operation. There is also, however, a direct biological action of low temperature which interferes with the activity of the nitrifying organisms. In the report on the purification of Boston sewage, just issued by the geological survey as Water Supply Paper No. 185, Mr. Phelps and I have compared the analytical results obtained at Brockton and Lawrence for the different months in the year, and the ratios there calculated show a very regular seasonal curve, the free and albuminoid ammonia and the oxygen consumed being highest in February at Lawrence, and in March at Brockton, while the nitrates reach a minimum at the same time. The maximum monthly deviation amounts to about 100 per cent., the worst monthly averages containing twice as much organic matter as the yearly average. Of course it is a well-known fact that the effluents from sand filters, although generally clear, are much more offensive in winter than in summer, but the exact extent of the damage as shown in this way is of some interest.

R. S. Weston. — Is it not possible that what we call over-septic treatment produces other changes in the character of the sewage than what we now believe? We aërate septic sewage to make it more applicable to the disposal beds. Do we do this to remove the toxins or to break down the colloidal or semi-soluble matter produced in the septic tank? Have we data enough to say definitely that there are enough toxins produced in septic tanks to interfere with the action of aërobic bacteria in the sewage disposal beds? Have we any more reason to say so than that colloids are the interfering bodies? This query seems

reasonable, especially in view of the paper presented at our last meeting by Mr. Eddy, in which he showed that long agitation and contact between suspended matter in sewage and the sewage itself renders a large part of that suspended matter semisoluble, so that after passing through the septic tank reprecipitation takes place, especially in the sewage disposal bed, which interferes with the efficiency of the latter. Is one position any more tenable than the other, in the light of our present data?

Prof. L. P. Kinnicutt. — I will say a word in regard to the removal of the color from sewage containing dye wastes. There is a difference in the action on different colors. There is rose aniline, which is removed very easily. Aniline black is very stable. If logwood is used, and the sand contains iron, then you get the same thing as ink, which remains in the effluent. I think it depends entirely on the kind of dyes used. Magenta or rose anilines, or aniline blues are easily taken out, while aniline black, or logwood mixed with iron in the sand, is very stable. It is merely a question of the kind of dye that goes into the sewage.

The Chairman. — One or two years ago Mr. Goodnough made a tour of the sewage plants during the winter. Will you give us an account, Mr. Goodnough, of what you observed at that time, especially at those plants which have not been touched upon this evening?

Mr. X. H. Goodnough. — I think what is true of the plants mentioned by the speakers to-night is true of most of the others. The plant at Pittsfield is, perhaps, in the coldest climate of any in the state. I visited that, not in the last year, but quite recently. That is operated in much the same way as the plants at Clinton and Brockton. The method in general followed everywhere is to ridge the beds in winter, or else to leave the beds with the corn hills after the corn is cut, and usually very little difficulty is found in disposing of the sewage through the winter season. It was a noticeable fact that during the very severe winter of 1903–1904 there was a great falling off in the efficiency of the purification at all of the filtration works. I think that practically without exception a greater amount of free ammonia and organic matter appeared in the effluent and a larger amount of iron. This was true of the new beds as well as of beds which had been in use a good many years. There was another very cold winter following that one, and the poorer effluents continued for two years. In most of them there has been some improvement since. At a good many of the smaller places the beds are

left flat in winter. If the beds are so arranged that a large dose can be applied very quickly, the experience seems to show that the plan is a satisfactory one. On the other hand, where the dose cannot be applied quickly, of course the tendency is for the beds to freeze up at points remote from the outlets. There is one very interesting filtration area which has not been mentioned to any great extent, and that is the one at Gardner. At Gardner the filter beds are small in area in proportion to the quantity of sewage, which runs up to from 250 000 to 300 000 gal. per acre per day, and at times to nearly double those quantities. The sewage is put through a very large tank, and afterwards, at times, through coke strainers and then applied to the filter beds. The filter beds are shallow and the quality of the effluent is not as good as in a good many of the other areas. Whether this is due to the fact that the sewage decomposes before application, — it is practically a septic sewage, — or to the character of the filtering material, or to the thinness of the beds or to the excessive quantity applied, I am unable at present to say. It may be classed with those beds which receive septic sewage and which, as a rule, give a poorer effluent than beds to which fresh sewage is applied.

[NOTE. Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by March 15, 1907, for publication in a subsequent number of the JOURNAL.]

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THE MECHANICS OF REINFORCED CONCRETE.

BY C. B. WING, MEMBER OF THE TECHNICAL SOCIETY OF THE PACIFIC COAST.

[Read before the Society, December 7, 1906.]

IN the past practical applications of the theoretical principles of mechanics have been largely confined to the design of structural members built of homogeneous materials, and the methods of making such applications are familiar to structural engineers. Recently the addition of metal to concrete for the purpose of increasing its power of resisting tensile stresses has come to be the practice in a large class of structural work. It is necessary, therefore, for the designer to consider the methods of applying the elementary fundamental principles of mechanics to the design of structural members built of non-homogeneous materials. This is a matter of some complexity, and on this account many empirical methods of avoiding the difficulties encountered have been suggested from time to time in the technical literature of the past few years. The writer believes that the use of empirical formulæ is unnecessary and in untrained hands may lead to dangerous results;* therefore, formulæ based upon accepted theoretical and experimental laws of the action of elastic materials under stress have been developed for a few of the cases arising in the design of reinforced concrete, and methods for their ready solution indicated.

The subject will be considered under three heads as follows:

Development of formulæ.

Principles and methods to be used in application of formulæ.

* Trans. Am. Soc. C. E., Vol. lvi, p. 390.

Comparison of results obtained by formulæ with results of tests.

Development of Formulæ.

The discussion will be limited to cases of direct tension, compression and simple cases of flexure.

Case I. *Simple tension or compression.* Concrete bar reinforced with metal bars imbedded in the concrete.

Required: The distribution of stress in the cross section of the bar between the concrete and metal.

Assumptions: (*a*) That the adhesion between the metal and concrete is perfect. (*b*) That there are no initial stresses. (*c*) That the maximum stresses are within the elastic limits of the materials.

Let P = Total load carried by the bar.
P_s = Portion of load carried by the metal.
P_c = Portion of load carried by the concrete.
A = Total area of cross section of bar.
A_s = Area of metal.
A_c = Area of concrete.
S_s = Stress per unit of area in metal.
S_c = Stress per unit of area in concrete.
E_s = Modulus of elasticity of metal.
E_c = Modulus of elasticity of concrete.
$n = \frac{E_s}{E_c}$ = The ratio of the respective moduli of elasticity of metal and concrete.
l = Length of bar.

As the load P is gradually applied, the bar is extended or compressed (*i. e.*, the metal and concrete are extended or compressed equally) an amount λ. From the ordinary theory of the action of elastic materials within the elastic limit,*

$$\lambda = \frac{P_s l}{A_s E_s} = \frac{P_c l}{A_c E_c}. \qquad (1)$$

From definition,

$$P = P_c + P_s = A_c S_c + A_s S_s. \qquad (2)$$

Substituting in (1) and solving,

$$P_s = \frac{A_s E_s}{A_c E_c + A_s E_s} \cdot P. \qquad (3)$$

* Merriman: Mechanics of Materials, p. 8, edition 1900; p. 24, edition 1905; Church: Mechanics of Materials, p. 209.

$$P_c = \frac{A_cE_c}{A_cE_c + A_sE_s} \cdot P. \qquad (4)$$

Dividing (3) by (4),

$$\frac{P_s}{P_c} = \frac{A_sE_s}{A_cE_c}. \qquad (5)$$

But,

$$\frac{P_s}{P_c} = \frac{A_sS_s}{A_cS_c}.$$

Therefore,

$$\frac{S_s}{S_c} = \frac{E_s}{E_c} = n. \qquad (6)$$

That is, the unit stresses in the steel and concrete are to each other as the moduli of elasticity of the respective materials; or, in other words, the unit stress in the steel of a reinforced concrete bar subjected to external forces of tension or compression is n times the unit stress in the concrete surrounding it.

Substituting the value of S_s or S_c from equation (6) in equation (2),

$$\left.\begin{aligned} P &= (A_c + nA_s)S_c \\ \text{or,} \quad P^1 &= \left(\frac{A_c}{n} + A_s\right)S_s \end{aligned}\right\} \qquad (7)$$

By assigning safe values to S_c and n or S_s and n in any given case, values of P and P^1 can be determined. The safe load for the column or bar will be the smaller of these two values. Conversely, equation (7) may be written,

$$A_c + nA_s = \frac{P}{S_c} \text{ or } \frac{nP}{S_s}. \qquad (7)'$$

Substituting safe values for S_c or S_s and n as before, the sum of the areas of the two materials required to carry a given load P can be determined. The safe area will be the larger of these two values.

Case II. *Flexure.* Three classes of problems arising in the use of reinforced concrete for beams will be considered.

(a) Symmetrical reinforced concrete beams with the reinforcing metal symmetrically placed with respect to the axes of the cross section of the beam.

(b) Symmetrical reinforced concrete beams with the reinforcing metal in the tension flange only.

(c) Unsymmetrical reinforced concrete beams with the reinforcing metal in the tension flange only.

(a) Symmetrical beams symmetrically reinforced.

Required: Distribution of stresses in the cross section of the beam and the moment of these stresses about the neutral axis, *i. e.*, "moment of resistance" of the section.

Assumptions: In addition to those given in Case I there will be:

(*d*) That the modulus of elasticity of concrete is the same for both tension and compression, and that within the limits of safe stress for the material it is practically constant.

(*e*) That Hooke's law — stress proportional to strain — is applicable to the distribution of stress within the limits of safe stress for the materials.

From equation (6) the unit stress in the metal at any point of the cross section is found to be n times the unit stress in the adjacent concrete. The moment of resistance of the metal will, therefore, be n times that of the same amount of concrete.

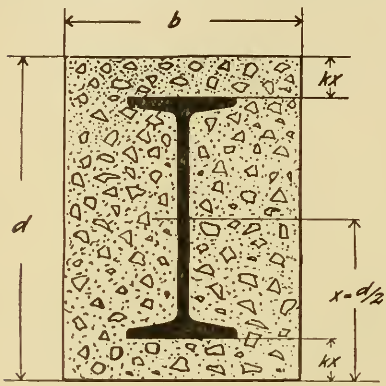


Fig. 1.

In Fig. 1 let I = the moment of inertia of the rectangle bd. I_s = the moment of inertia of the metal. The moment of resistance of the internal horizontal forces will be according to the ordinary theory of flexure,*

$$\frac{S_c(I - I_s)}{c} + \frac{nS_c(1 - k)I_s}{c - kc} = M$$

in which $c = x = \frac{d}{2}$. Reducing and simplifying there results,

$$\frac{S_c\,[I + (n - 1)I_s]}{c} = M. \quad (8)$$

The method of using equation (8) for the solution of problems is the same as for ordinary cases of flexure and needs no

* Merriman: Mechanics of Materials, p. 51; Church, Mechanics of Materials, p. 249.

further discussion. Equation (8) applies equally well to cases similar to that shown in Fig. 2.

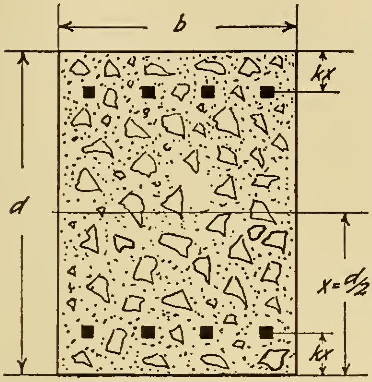


Fig. 2.

The maximum unit stress in the metal in either case is $S_s = nS_c$ $(1 - k)$. If $n = 10$ and $S_c = 300$, the unit stress in the metal is less than 3 000 lb. per sq. in. As the ordinary safe unit stress for metal is 16 000 lb. per sq. in., the use of metal in concrete beams of this form is decidedly uneconomical unless the design is such that the concrete can be applied to the steel after the structure has received a large portion of the load it is expected to carry.

(b) Symmetrical beams unsymmetrically reinforced.

The requirements and assumptions are the same as for beams of class (a). Two conditions of stress will be considered; (1) The action of the beam up to the point of tensile rupture of the concrete; (2) the action of the beam after tensile rupture of the concrete has taken place up to the point of failure of the concrete in compression or to the elastic limit of the steel in tension.

(1) Considering the tensile strength of the concrete available for carrying stress.

The ordinary theory of flexure requires that the sum of the horizontal forces above the neutral axis shall equal the sum of the horizontal forces below the neutral axis of the cross section. As the tensile strength of concrete is less than the compressive strength, in order to develop the strength of the concrete as fully as possible it is desirable to have the neutral axis of the beam nearer the bottom than the top. To bring about this result with a beam composed entirely of concrete, and at the same time meet the requirements of the theory of flexure as stated above, the beam should have a cross

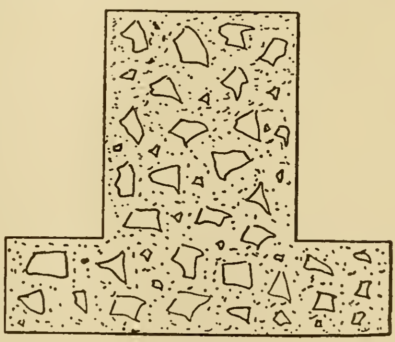


Fig. 3.

section as shown in Fig. 3, or in the cross section shown in Fig. 4, a certain amount of metal area A_s must be provided below the neutral axis.

Let Fig. 4 represent the distribution of the stresses in the

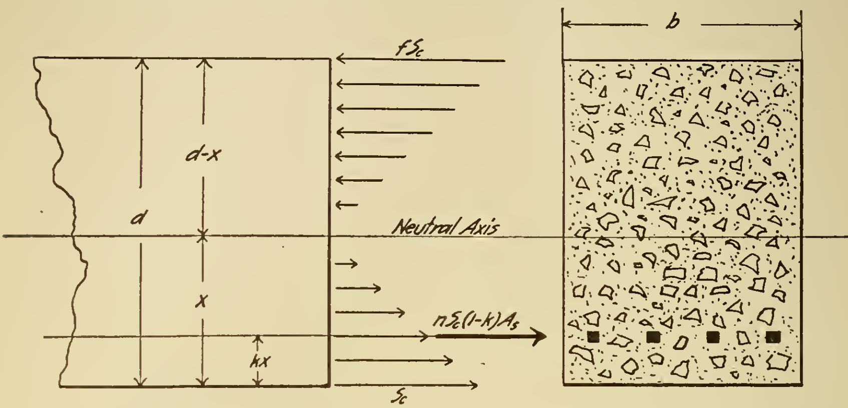


Fig. 4.

cross section of an unsymmetrically reinforced concrete beam in flexure.

Let l = Span of beam.
b = Width of beam.
d = Depth of beam.
x = Distance of neutral axis from bottom of beam.
kx = Distance of center of metal reinforcement from bottom of beam.
A_s = Sectional area of metal; usually small when compared with the area of the concrete.
$n = \frac{E_s}{E_c}$ = Ratio of respective moduli of elasticity of metal and concrete.
f = Ratio of maximum compressive unit stress of concrete to maximum tensile unit stress.
S_c = Maximum tensile unit stress in concrete.
S_s = Tensile unit stress in metal.
M = The moment of resistance of the cross section.

The position of the neutral axis will vary as f varies and for any given value of f will be determined by the proportion (see Fig. 4),

$\frac{x}{S_c} = \frac{d-x}{f\,S_c}$, from which is derived the equation,

$$x = \frac{d}{f+1}. \qquad (9)$$

The unit stress S in the concrete surrounding the metal is given by the proportion,

$$\frac{S_c}{x} = \frac{S}{x(1-k)}.$$

$\therefore S = S_c(1-k)$, and from (6) the unit stress in the metal is

$$S_s = \frac{E_s}{E_c} S = nS_c(1-k). \qquad (10)$$

The algebraic sum of the horizontal stresses acting on the cross section is, therefore (see Fig. 4),

$$\Sigma SdA = \frac{fS_cb(d-x)}{2} - \frac{S_cbx}{2} - nS_c(1-k)A_s.$$

Equating this sum to zero, substituting the value of x from (9) and solving, there results the equation,

$$A_s = \frac{(f-1)bd}{2n(1-k)},$$

or,

$$f = \frac{nA_s}{bd} 2(1-k) + 1. \qquad (11)$$

The moment of these stresses about the neutral axis gives the moment of resistance of the cross section as follows:

$$M = \frac{fS_cb(d-x)}{2} \cdot \frac{2}{3}(d-x) + \frac{S_cbx}{2} \cdot \frac{2}{3}x + nS_c(1-k)A_s \cdot x(1-.$$

Substituting the values of x and A_s from (9) and (11), there results the equation,

$$M = S_cbd^2 \cdot \left[\frac{f^3+1}{3(f+1)^2} + \frac{(1-k)(f-1)}{2(f+1)}\right]. \qquad (12)$$

It should be noted that this equation is similar in form to the ordinary flexure equation $M = \frac{SI}{c}$, the quantity $bd^2[\ ]$ being the section modulus or $\frac{I}{c}$ of the beam, in which

S = the unit stress in the outer fiber.
I = the moment of inertia of the cross section.
c = the distance of the outer fiber from the neutral axis of the cross section.

Theoretically the above formulæ will correctly represent the action of reinforced concrete beams up to the point of failure

of the concrete in tension, provided that point and its elastic limit are coincident. The error, if any, in this assumption is small and practically may be neglected.

(2) Neglecting the tensile strength of the concrete.

With tensile strength in the concrete destroyed by flaws or stresses beyond the point of tensile rupture, the quantity $\frac{S_c bx}{2}$ drops out of the summation of the horizontal stresses acting on the section, and equation (11) becomes

$$A_s = \frac{f^2}{2n(1-k)(f+1)} bd;$$

or,

$$f = \frac{nA_s}{bd}(1-k) \pm \sqrt{\frac{nA_s}{bd}(1-k)\left[\frac{nA_s}{bd}\cdot(1-k) - 2\right]} \qquad (13)$$

and similarly equation (12) becomes

$$M = fS_c bd^2\left[\frac{f^2}{3(f+1)^2} + \frac{f(1-k)}{2(f+1)^2}\right]' \qquad (14)$$

Equation (14) may be readily changed by substituting for S_c its value from equation (10). Thus,

$$M = S_s bd^2\left[\frac{f^3}{3n(f+1)^2(1-k)} + \frac{f^2}{2n(f+1)^2}\right]'' \qquad (15)^*$$

(c) **Unsymmetrical reinforced concrete beams unsymmetrically reinforced.** The T beam or ribbed floor slab is the principal beam in practical use falling under this classification. Formulæ for designing this type of beam may be derived in a manner similar to that used in the previous cases. Such formulæ are more complicated in form and cannot be so readily solved graphically. To consider a wide thin floor slab as part of the compression flange of the supporting beam is questionable from a practical standpoint. In the present state of knowledge of the action of such beams, and considering the danger of lack of continuity in their construction, the conservative engineer would design the rib to carry the load and consider the slab as transferring the floor load from each side to the rib. The portion of the floor slab directly over the beam may be considered as part

* Since the above was written Professor Merriman has proposed a formula derived in a similar manner, considering a portion of the tensile stresses as always available for carrying stress. The results obtained by such a formula would not vary greatly from those obtained by use of formula (12).

of the beam if careful provision is made for its construction at the same time that the remainder of the beam is laid. For the above reasons the formulæ for this case will not be presented at this time.

Principles and Methods to be used in Application of Formulæ.

Equations (7) and (12) are proposed for use in designing reinforced concrete, and with their various modifications are applicable to most of the cases arising in practice. No originality is claimed for these formulæ other than the similarity of the beam formulæ to the formulæ in use for beams of homogeneous materials, and the ease with which the section modulus can be obtained by use of diagram or tables. Equation (7) is applicable to cases of direct tension or compression and equation (12) with the other subordinate or similar equations to ordinary cases of flexure. These equations involve the loads to be carried, certain constants the values of which depend upon the physical properties of the materials supporting the loads, and the cross-sectional area of these materials. The loads to be carried and the physical properties of the materials to be used in any given case being known, the required cross-sectional areas of the materials can be determined by numerical substitution in the proper formula.

The loads to be carried depend upon the position of the member to be designed in the structure of which it is a part and are usually expressed as so many pounds or tons of force acting in the direction of the longitudinal axis of the member, in cases of direct tension or compression, or as so many inch-pounds or foot-tons of bending moment if the member to be designed is subjected to flexure. The method of obtaining these forces and moments is not a part of the present discussion and they, therefore, may be assumed as known quantities in any given case.

The physical properties of the various kinds of metal available for reinforced concrete construction are readily determined and for any given material they are reasonably constant. Concrete, on the other hand, is variable in composition and the designer is confronted with a large mass of conflicting data regarding the physical properties of this material. It is not necessary to the present discussion to go into an extended investigation of the experimental data concerning the physical properties of concrete. The object of the discussion is to present a method by which safe and economical designs can be readily obtained provided the loads to be carried are accurately known and con-

servative values of the physical properties of the materials used are assumed. It is not out of place, however, to indicate what values of the physical properties of the materials are conservative. Thus an inspection of equation (7) shows that one unit of sectional area of metal in a reinforced concrete bar is equivalent to n units of concrete. The right-hand term of equation (7), which gives the load P a given bar can carry, varies directly as n, the ratio of the moduli of elasticity of the materials, and as S_c, the tension unit stress for concrete. Therefore, low values of these quantities are conservative. A low value of n is obtained by the assumption of a low value of the modulus of elasticity of the reinforcing metal and a *high* value of the modulus of elasticity of the concrete. This latter point is of great importance and should be carefully considered in choosing physical constants for reinforced concrete designs.

In recent discussions of reinforced concrete design much emphasis has been laid upon the fact that the elastic limit of the metal determines the ultimate strength of a reinforced concrete beam In determining the safe unit stresses to be used in designing steel structures more and more attention is rightly being paid to the elastic limit of the metal as the real measure of the maximum stress the material will stand without failure of the structure, the ultimate or breaking strength of the material being considered as relatively unimportant. In like manner the point at which the concrete in reinforced concrete construction fails in tension, and *not* the elastic limit of the metal, is probably the real measure of the maximum stress to which the member should be subjected without endangering the safety of the structure of which it forms a part. This is especially true if the concrete is assumed to protect the metal from excessive heat or corrosion.

The great advantage of reinforced concrete construction is that the approximate strength and cost of a metal structure is obtained with the durability and heat resisting qualities of masonry. If, however, the design is such that cracks are allowed to form, as they surely do if the stresses exceed the tensile strength of the concrete, it is doubtful if the qualities of durability and fire-proofness are obtained. If these qualities are not obtained the chief advantage of the combination of the materials is lost.* The design of reinforced concrete structures should, therefore, be based upon the assumption of conservative

* *Engineering News*, Vol. lv, p. 291. Ninety-one cracks observed in 13 beams on application of *working* load.

values of the moduli of elasticity of the materials, and maximum stresses in excess of the ultimate strength of the concrete in tension should be avoided.

An acceptance of the above principle greatly simplifies the work of the designer, because in the majority of cases it renders unnecessary lengthy and involved considerations of shearing stresses and adhesions between metal and concrete. At least in the design of reinforced concrete beams consideration of these subsidiary questions occupies the same place that consideration of shearing stresses occupies in the design of wooden beams; that is, the main proportions are determined by the theory of flexure, and certain special cases are afterward investigated to determine their ability to resist stresses other than those due to simple flexure.

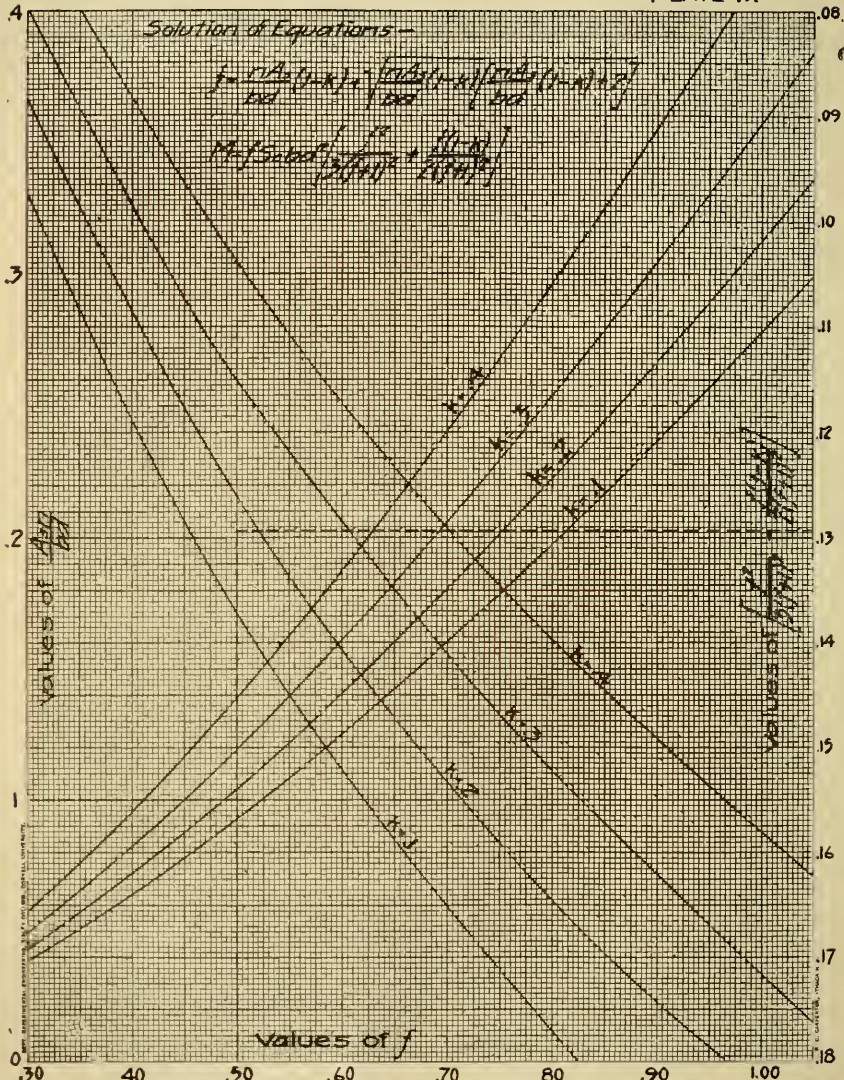
The method of using equation (7) for the design of reinforced concrete bars or columns subjected to direct tensile or compressive stresses needs no further explanation.

If conservative values of S_c and n are assumed the results obtained by substitution in the proper formula should be practical and safe, provided the ratio of the length to the least diameter of columns does not exceed 12. Special cases involving ratios greater than this should be designed by practical rather than theoretical considerations.

The metal in reinforced concrete carries per unit of area n times the stress in the adjacent concrete. The use of metal, therefore, in any given case to carry compressive stresses will not be economical unless its cost per cubic unit is less than n times the cost of a cubic unit of concrete. With steel at 2 cents a pound, and concrete at 30 cents a cubic foot, the cost of steel per cubic unit will be 32 times the cost of concrete per cubic unit. The value of n would have to be 32 for the cost of carrying a given stress by steel or concrete to be the same. An examination of experimental data shows the probable value of n even in extreme cases to be less than 16. It is safe to say, therefore, that measured by its stress-carrying power the steel in a reinforced concrete column costs twice as much as an equivalent amount of concrete. The use of concrete with longitudinal reinforcement subjected to direct compressive stresses is, therefore, uneconomical and not justified unless the concrete can be applied after the metal is under stress, and in such cases the metal should be designed of sufficient strength to carry all the loads and the concrete treated merely as a protective coating. The economical use of reinforced concrete is thus shown to be

confined to that class of masonry structures in which it is impractical to design them so that all tensile stresses are avoided. In the majority of such cases the tensile stresses are due to

PLATE II.



beam action, and their probable amount and intensity can best be determined by the application of the ordinary theory of flexure.

Equation (12) and its subsidiary and modified forms are

proposed for the investigation of the distribution of stresses in structures of this character and inversely for designing reinforced concrete beams to resist safely given external forces. An examination of the right-hand portion of equation (12) shows it to be of the same general form as the equation for the moment of flexure for simple beams. The quantity $bd^2[\ ]$ as previously stated takes the place of the expression $\frac{I}{c}$ or section modulus in the ordinary flexure formula $\frac{SI}{c} = M$. The method of using equation (12) for designing beams is, therefore, simple and well known as soon as the value of the quantity inside the bracket is determined. Discussion of the method of applying this equation to the design of beams will, therefore, be confined to the determination of this quantity.

Preliminary to a discussion of this point it will be necessary to consider the factors influencing the amount of steel reinforcement to be used in the tension flanges of a reinforced concrete beam. As shown in the discussion of columns, for the purpose of carrying stress, steel in reinforced concrete is at least twice as expensive as an equivalent amount of concrete; and if concrete could be relied upon to carry tensile stresses safely, the use of steel in combination with it could not be justified economically. The determination of the amount of steel reinforcement to be used in the tension flange of a reinforced concrete beam should, therefore, be based on data obtained from experiment and practical use and is not a subject for theoretical investigation.

The amount of steel used in the tension flange of a reinforced beam is usually expressed as a percentage of the total area of the cross section. Referring to equation (11) it is seen that if A_s is expressed as a certain percentage of bd, n and k are the only other quantities contained in the right-hand portion of that equation. The method for assuming a value of n has already been stated. The determinaton of a proper value of k is best obtained by trial designs. In practical designs its range of values is small and the second trial usually determines the proper value for a given case with sufficient accuracy.

For economy the metal should be as near the lower surface of the beam as consistent with protection of the metal from corrosion and proper adhesion between metal and concrete.

The section modulus of a reinforced concrete beam corresponding to a given value of $\frac{M}{S_c}$ is, therefore, obtained, as follows:

Values of n, A_s and k are assumed, and the corresponding value of f from equation (11) determined; this value is then substituted in the bracket of equation (12), giving the coefficient of bd^2 to be used in completing the section modulus. The determination of the required dimensions of the beam from this point is the same as for ordinary beams of timber or other homogeneous material. Numerically this is a long and tedious process, comparable to the numerical determination of the section modulus of a steel I beam. Plates I, II and III, however, give ready graphical solutions of the equations for the various cases under consideration.

Plate I is applicable to the solution of problems in which the tension in the concrete is taken into consideration. Thus, to give a direct illustration, for a given case let A_s be assumed equal to $\frac{1}{100}bd$, n equal to 10 and k equal to 0.2.

Entering Plate I on the left-hand ordinate at a value of

$$\frac{A_s n}{bd} = \frac{\frac{1}{100}bd \times 10}{bd} = 0.1,$$

and moving horizontally to the right until the diagonal line corresponding to a value of $k = 0.2$ is intersected, the value of $f = 1.16$ is found on the horizontal scale at the bottom of the sheet vertically beneath this point; then following this vertical line up until it intersects the diagonal line at the top of the sheet corresponding to the value of $k = 0.2$, the value of the [ ] = 0.213 of equation (12) is found on the vertical scale at the right side of the plate horizontally to the right of this point. Similar values may be obtained from Plates II and III in the same manner.

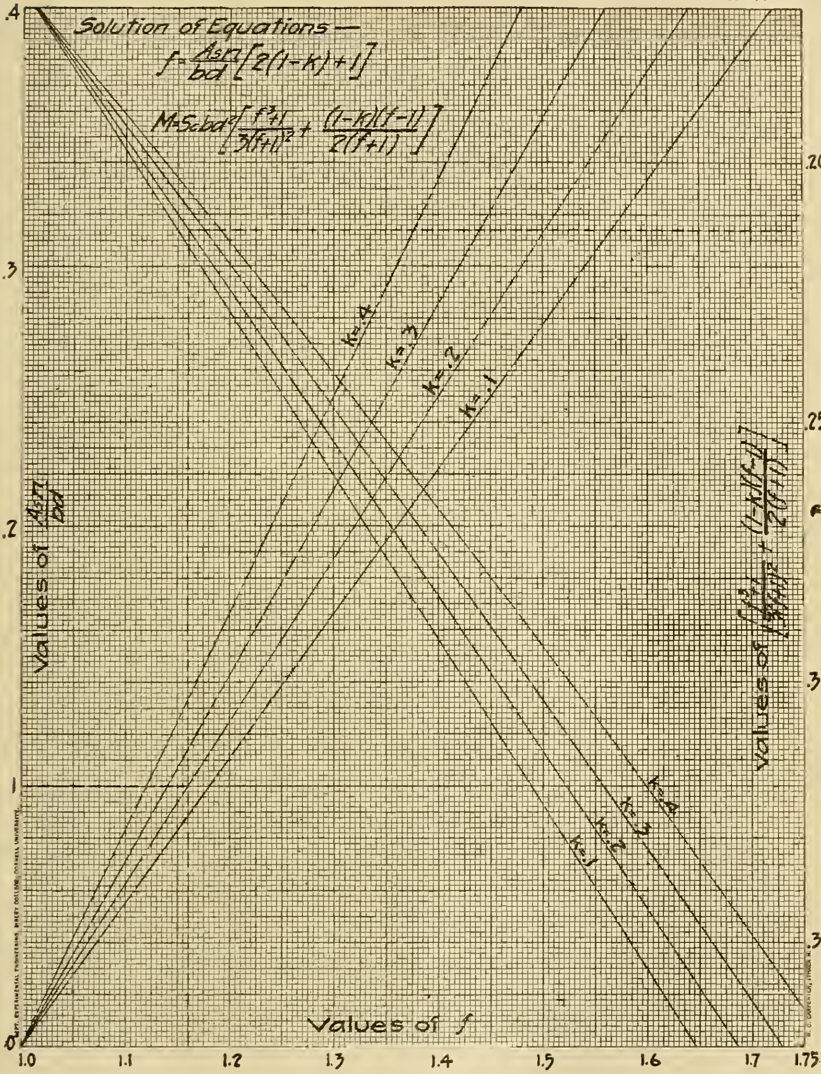
The method of using equations (12), (14) and (15) and Plates I, II and III for determining the cross section necessary to resist the action of an external bending moment will be more fully illustrated by the solution of the following examples:

Example 1. Required, the cross-sectional area of a rectangular reinforced concrete beam to resist safely the action of an external bending moment of 120 000 in.-lb.

Assume $S_c = 300$ lb. per sq. in.
$n = 10$
$k = 0.2$
$A_s = 0.5$ per cent. bd.

From these $\frac{A_s n}{bd} = 0.05.$

PLATE I.



Substituting in equation (12), the required section modulus is found to be

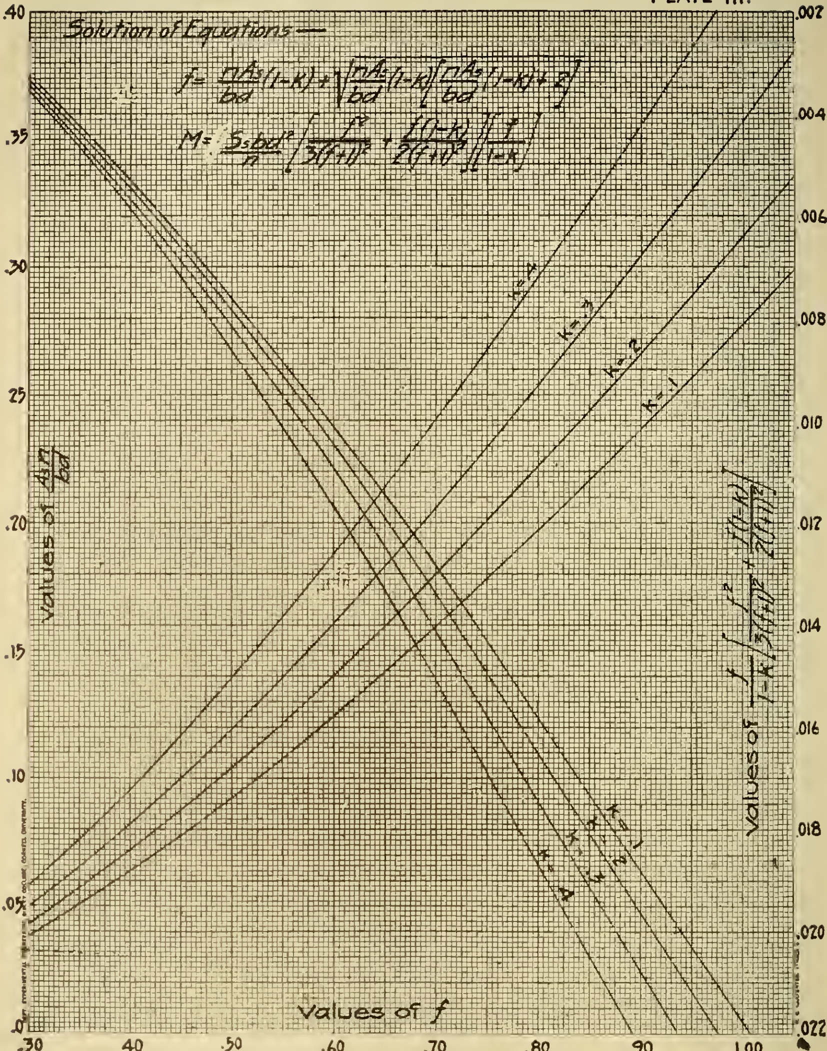
$$d^2\,[\;] = \frac{120\,000}{300} = 400.$$

From Plate I, by methods previously indicated, the value of the [ ] = 0.190 is found. This gives

$$bd^2 = \frac{400}{0.19} = 2\,100 \text{ cu. in.},$$

from which, if $b = 12$ in., the value of $d = 13.25$ in. is found.

PLATE III.



Substituting this value, and the value of $f = 1.08$ obtained from Plate I in equation (9), there results the value

$$x = \frac{13.25}{1.08 + 1} = 6.36 \text{ in.},$$

and $kx = 0.2 \times 6.36 = 1.27$ in., a value that is satisfactory for the design in question, and consequently the assumed value of $k = 0.2$ is found to have been correct. The unit stress in the steel is found by substitution in equation (10) to be

$$S_s = 10 \times 300 \, (1 - 0.2) = 2\,400 \text{ lb. per sq. in.}$$

and the maximum unit compression stress in the concrete is

$$fS_c = 1.08 \times 300 = 324 \text{ lb. per sq. in.}$$

The above solution of the problem is based on the assumption that the tensile strength of the concrete is available for carrying stress.

The design must now be tested to determine the maximum stresses in the concrete and steel if at the point of maximum external moment the tensile strength of the concrete is destroyed. This investigation can be made by use of equations (13), (14) and (15) and their solution is made easy by the use of Plates II and III. Substituting in equation (14) by use of Plate II,

$$fS_c = \frac{M}{bd^2[\ ]'} = \frac{120\,000}{2\,100 \times 0.0935} = 611 \text{ lb. per sq. in.,}$$

and substituting in equation (15) by use of Plate III,

$$S_s = \frac{M}{bd^2[\ ]''} = \frac{120\,000}{2\,100 \times 0.0038} = 15\,000 \text{ lb. per sq. in.}$$

As these values are safe the design can be considered a fairly satisfactory one. It should be noted, however, that a complete failure of the concrete in tension would change the unit stress in the metal from 2 400 lb. per sq. in. to 15 000 lb. per sq. in., thus increasing the unit elongation approximately six times. This in beams having the maximum moment extending over a considerable length would, undoubtedly, cause some opening of hair cracks and might cause ultimate failure of the metal if the same is ever exposed to corrosion or heat. The results of the above computation at least suggest the necessity of experimental investigation along the lines of determining the effect of hair cracks on concrete as a protective coating.

In order to more clearly illustrate the range of use of the formulæ and plates another application will be made.

Example 2. Find the capacity of the beam of the previous problem when reinforced with 1.5 per cent. of metal instead of 0.5 per cent. This gives

$$\frac{A_s n}{bd} = \frac{\frac{1.5}{100} bd \times 10}{bd} = 0.15.$$

Substituting in equation (12) by use of Plate I with $k = 0.225$,

$$M = 300 \times 2\,100 \times 0.2325 = 146\,500 \text{ in.-lb.}$$

Substituting the value of $f = 1.235$ obtained from Plate I in equation (9), there results,

$$x = \frac{13.25}{1.235 + 1} = 5.93 \text{ in.}$$

and

$$kx = 0.225 \times 5.93 = 1.33 \text{ in.},$$

a value that very nearly corresponds to the value obtained in the previous case, showing the assumed value of $k = 0.225$ to have been approximately correct.

Substituting in equation (10), the unit stress in the steel is found to be

$$S_s = 10 \times 300(1 - 0.225) = 2\ 325 \text{ lb. per sq. in.},$$

and the maximum compressive unit stress in the concrete is

$$fS_c = 1.235 \times 300 = 370 \text{ lb. per sq. in.}$$

Testing for the unit stresses on failure of the concrete in tension there results by use of Plates II and III,

$$fS_c = \frac{146\ 500}{2\ 100 \times 0.1395} = 500 \text{ lb. per sq. in.}$$

and

$$S_s = \frac{146\ 500}{2\ 100 \times 0.011} = 6\ 340 \text{ lb. per sq. in.}$$

These values are much less than those obtained in the previous case, showing less danger from the opening of serious cracks.

The formulæ proposed are thus shown to be readily applicable to the design of reinforced concrete beams whether the tension in the concrete is considered or not, and have the advantage of enabling the designer to obtain the stresses in the concrete and steel, with equal ease, for either assumption.

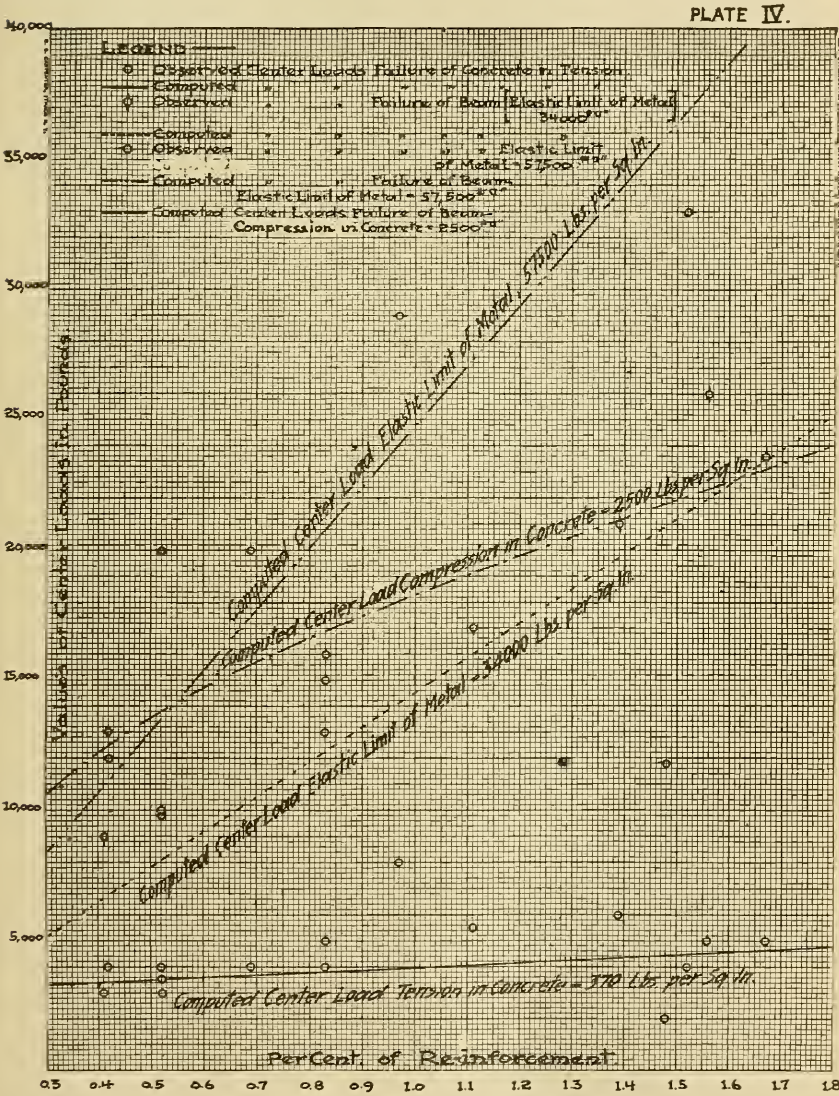
Comparison of the Results obtained by Formulæ with the Results of Tests.

For the purpose of comparing the results obtained by use of the proposed formulæ with the results of tests, the center load at the point of apparent failure of the concrete in tension has been taken from the plotted results of Professor Talbot's tests of reinforced concrete beams.* In most cases this point could

* Bulletin No. 1, University of Illinois Engineering Experiment Station. Talbot, A. N.: Tests of Reinforced Concrete Beams.

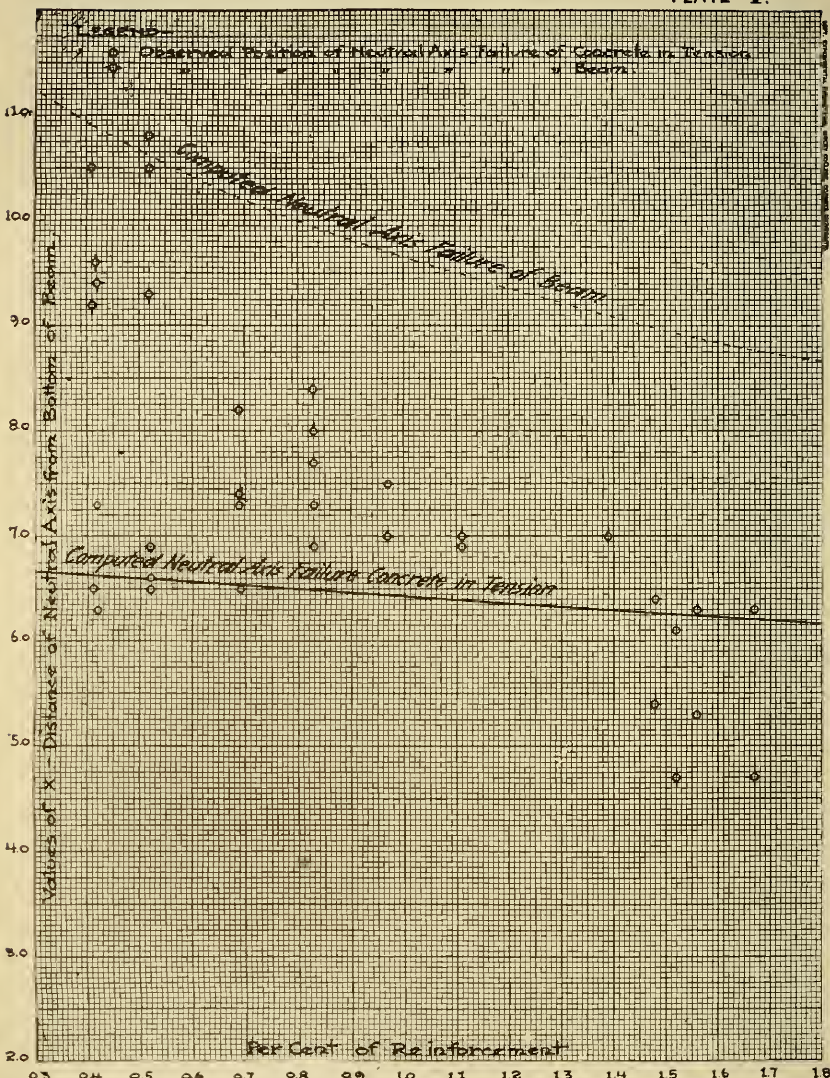
be determined from the published diagrams with sufficient accuracy for the purpose of the present comparison. The observed position of the neutral axis at this point as determined

PLATE IV.



by extensometer has also been recorded. Similar quantities have been computed by means of the proposed formula and the results tabulated in Table I and shown graphically on Plates IV and V.

PLATE V.



For this purpose the bending moment of the external forces in inch-pounds, including the weight of the beam, has been taken as

$$M = 28\,P + 49\,400,$$

M being the bending moment in inch-pounds and P the center load. Substituting this quantity in equation (12) there results

$$P = \frac{S_c b d^2}{28} \left[\quad\right] - 1\,764.$$

TABLE I.

No. of Beam.	Per Cent. and Kind of Reinforcement.	Apparent Center Load. Failure of Concrete in Tension.	Calculated Center Load. Tension in Concrete 370 Lb. per sq. in.	Apparent X	Calculated X	Apparent Center Load. Failure of Beam.	Calculated Center Load. Elastic Limit of Metal.	Calculated Center Load. Compression in Concrete, 2 500 Lb. per sq. in.	Apparent X Failure of Beam.	Calculated X Failure of Beam.
17	.52 P ▯	3500	3510	6.9	6.6	10000	8000	13800	10.8	10.6
21	.41 P o	3000	3440	6.5	6.6	9000	6600	12300	9.2	10.9
27	1.56 P ▯	5000	4460	5.3	6.2	26000	22000	22400	6.3	8.9
16	.52 P ▯	3000	3510	6.5	6.6	9800	8000	13800	10.5	10.7
19	.41 P o	3000	3440	6.5	6.6	9000	6600	12300	10.5	10.9
10	.83 T	4000	3800	7.3	6.5	15000	12300	16600	7.7	9.9
15	.83 T	5000	3800	6.9	6.5	16000	12300	16600	8.4	9.9
14	1.11 K	5500	4050	6.9	6.4	17000	15900	19100	7.0	9.5
4	1.39 K	6000	4300		6.3	21000	19900	21200	7.0	9.1
22	1.67 K	5000	4560	6.3	6.2	23600	23900	22800	4.7	8.8
5	.83 K	5000	3800	7.7	6.5	13000	11900	16600	8.0	9.9
29	1.48 J	2000	4380	6.4	6.3	11800	35900	21800	5.4	9.0
3	.42 J	4000	3440	7.3	6.6	12000	11200	12500	9.6	10.8
7	.42 J	4000	3440	6.3	6.6	13000	11200	12500	9.4	10.8
20	.69 J	4000	3670	6.5	6.5	20000	17000	15600	7.4	10.2
2	.69 J	8000	3670	7.3	6.5	20000	17000	15600	8.2	10.2
13	.97 J	8000	3810	7.5	6.4	29000	24200	18100	7.0	9.7
28	1.52 J	4000	4410	6.1	6.2	33000	36800	22000	4.7	8.9
9	.52 R	4000	3510	7.3	6.6	20000	13500	13800	9.3	10.6

As near as could be determined from a study of the tests of the plain concrete, the value of $n = 7.5$ for these tests is probably nearly correct. The tests of the plain concrete beams give $S_c = 370$ lb. per sq. in. as the average value of the modulus of rupture of the concrete as determined by the ordinary theory of flexure. Substituting these values in the above formula, the results given in Table I and on Plate IV have been obtained.

A study of these results shows that at the point of failure of the concrete in tension the computed results for center load and position of the neutral axis agree with the results of the experiments as closely as could be expected. The computed straight lines of Plates IV and V in each case fairly average the plotted field of the tests. The computed results for center load and neutral axis at the point of failure of the beam do not agree as well with the results of the tests. The computed results, however, are on the side of safety and have approximately the same variation for all percentages of reinforcement.

This lack of agreement is undoubtedly due to the fact that even at the point of rupture of the beam there is a portion of the concrete carrying tensile stresses.* These tensile stresses could be included in the formula, but from a practical standpoint merely lead to needless complication. This is especially true if the point of failure of the concrete in tension is conceded to be the real measure of the strength of reinforced concrete beams in the same sense as the elastic limit of metal is considered to be the real measure of the strength of metal beams.

Conclusion.

Many formulæ for the design of reinforced concrete beams have appeared in the technical literature of the past ten years.

They may be divided into two classes:

Those considering the tension in the concrete and those neglecting the tension in the concrete.

By substituting the notation of the present article the variation of those formulæ from the formulæ here proposed can be readily determined and in some cases will be found to be slight. Thus, the formulæ of M. Considère † would be the same if the total tension in the concrete had been taken by him as $\frac{1}{2} S_c bx$ instead of $S_c bx$ (Fig. 1).

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* The formula proposed by Professor Merriman would correct this error to a certain extent.

† Considère, A.: Experimental Researches on Reinforced Concrete; translated by Moisseiff, L. S., New York, 1903.

The formulæ that consider the stress in the concrete to vary as the ordinates of a parabola instead of a straight line give in equation (12) coefficients of $\frac{5}{12}$ and $\frac{2}{3}$ instead of $\frac{4}{12}$ and $\frac{1}{2}$ in the terms within the brackets of the right-hand member of that equation.

It is worthy of note that the late Prof. J. B. Johnson was one of the first to propose a formula identical with equation (14).*

The formulæ here proposed do not, therefore, vary materially except in arrangement and notation from some that have been quite generally accepted.

The arrangement here given has been chosen because of its similarity to that in use in the discussion of homogeneous beams, and Plates I, II and III have been prepared to serve a purpose similar to that served by the tables of properties of I beams in manufacturers' hand books.

It is hoped that a thorough discussion of the subject at this time will lead to a simplification of the methods for designing reinforced concrete and a better understanding of the difficulties and dangers encountered by the use of improper methods.

NOTE. — DISCUSSION of this paper is invited, to be received by Fred. Brooks, 31 Milk Street, Boston, by April 15, 1907, for publication in a subsequent number of the JOURNAL.]

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* *Engineering News*, 1895, i, 10.

REINFORCED CONCRETE CONSTRUCTION: ITS PROPER APPLICATION IN EARTHQUAKE COUNTRIES.

By Charles Derleth, Jr.

[Read before the Technical Society of the Pacific Coast, December 7, 1906.]

Introduction.

Ever since April, 1906, the date of our earthquake and attendant fire in San Francisco and Santa Rosa, greater and renewed interest has been shown, the country over, regarding the merits of reinforced concrete construction, and in particular regarding its applicability in the design of city buildings. For some years interest in this type of construction has been rife, and since the San Francisco disaster the subject seems to have been stirred to the limit of discussion. Unfortunately, at the time of our earthquake and fire, there were in San Francisco no true reinforced concrete buildings. A discussion of the subject, therefore, in the light of earthquake and fire damage within the earthquake belt, is necessarily meager, and arguments in favor of reinforced concrete construction cannot be altogether convincing.

The little reinforced concrete construction which already existed in San Francisco prior to the fire was mainly found in floors and interior columns. It is well known that floors and interior columns, irrespective of the particular materials of which they are built, suffered very little, if any, from earthquake vibration. Such parts of building frames in general were not subjected to severe earthquake stress or destruction. Consequently it may be concluded that nothing very definite can be stated regarding the earthquake resistance of this type of construction. Comparison, of course, must be made to first-class fireproof steel frame buildings, and not to that type of construction locally known as class B and class C. Arguments that may be advanced must be limited mainly to fire damage and fire resistance.

There were some examples of reinforced concrete retaining walls within the burned district. These walls were of rather bold design. In their highest parts they were 35 ft., and were built with counterfort ribs spaced about 8 ft. center to center. They were not injured by the earthquake, and naturally not by the fire.

There were a number of reinforced concrete buildings within the Bay region of San Francisco which were not subjected to subsequent fire, and all evidence in these cases, though necessarily extremely restricted, is decidedly favorable to reinforced concrete as a type of construction to withstand earthquake motion for well-built structures not to exceed six stories in height.

The subject is broader, however, than the study of effects in the recent San Francisco disaster. Within the past few weeks we have heard of the failure of alleged reinforced concrete members, or the collapse of so-called reinforced concrete buildings, in different parts of the country. In all such cases the enemies of reinforced concrete construction at once find arguments to condemn this type of building. I believe that reinforced concrete construction for such buildings must not only be defended from its so-called friends, but at the same time its good qualities and its limits of adaptability must be explained and called to the attention of those who do not seek to be its advocates. The construction as a type must not be condemned by the citation of a particular failure, especially when the example given represents a most faulty case of design. Moreover, where the so-called friends of reinforced concrete have devoted this excellent combination of materials to a purpose for which the combination is not well suited, and under conditions of design which indicate a decided lack of knowledge and appreciation of the mechanical principles involved, then it is the duty of qualified engineers to call attention to the faults and weaknesses of the resulting structures. In all such cases, the attention of property owners and prospective builders should, wherever possible, be called to the specific inherent defects of design which have caused the failure, or, in general, which may, and often do, produce failure; and in such cases the engineering critic should take pains to emphasize that the collapse or destruction of whatever kind has been the result of bad designing, and that it is entirely independent of the particular kind of materials used, be they reinforced concrete on the one hand, or rolled steel shapes on the other.

Unfortunately, there are too many cases of inadequate design and improper methods of field construction for reinforced concrete, which are daily being forced upon the building public, and it is the duty of conservative engineers now to protect a meritorious class of construction at a time when its reputation is apt to be ruined by a host of incompetent persons who are claiming expertness in its use and application.

No sooner had the news been spread that the Bixby Hotel * at Long Beach, California, had collapsed, than it was at once proposed by one of the labor organizations of the state to appoint a commission for the purpose of investigating the disaster and placing the blame. It was promptly suggested by this organization that engineering talent be commissioned to examine the collapse and to inquire primarily whether the failure was due to the fact that the building was constructed of concrete and steel. It would appear that there are many interests ready and alert to find evidence against and to condemn the use of reinforced concrete, and I repeat, it is necessary at this time not merely to protect the material against some people who believe themselves its friends, but also against those interests which are naturally averse to its introduction.

Calculations.

The paper by Mr. C. B. Wing, presented this evening, and dealing with proposed formulas and tables for the practical calculation of reinforced concrete beams, leads me to say something regarding the great need at this time of greater uniformity in method of calculation, greater simplicity in the treatment of theoretical considerations and a lesser tendency to the use of specialized empirical formulas.

During the past few years much has been written regarding theories for the mechanical action of reinforced concrete beams and columns, and a host of authors have advanced as many different formulas. It would seem almost that no two engineers can agree even for the simplest calculations; as a result, the layman has been lead to believe that it is not possible to handle the design of reinforced concrete members with that degree of exactness and certitude which is assigned to the calculation of rolled steel members.

We should have greater uniformity in method for calculating the strength and proportioning the parts of such simple members as beams and columns. There is no reason why such members should not be designed and proportioned by applying the well-established principles of statics. There is no reason why we should insist upon a peculiar and more complex assumption for the variation of fiber stress in a concrete-steel beam than the

* For a description of the collapse and for other information relating to the design of the Bixby Hotel, consult: 1. *Engineering News*, Vol. lvi, page 555, November 29, 1906; 2. *The Architect and Engineer of California*, November, 1906, article by Mr. John B. Leonard.

simple straight-line law which satisfies us in the case of rolled steel. Special formulas bearing the names of so-called expert authors are unnecessary; in fact, they are misleading, confusing and pernicious. Fantastic theories which introduce a parabolic law of variation of fiber stress have absolutely no foundation in fact when we remember that we are dealing with working compressive stresses in the concrete, and not ultimate stresses, and when Hooke's law is assumed to hold at the same time; indeed, such laws for fiber stress variation have no especially practical merit and lead to no essentially different or more accurate results than would be obtained by the more rational straight-line law, and in general by more straightforward procedure.

Let us abandon special formulas, which we have not time to carefully examine, and whose practical limits of application are not given. Let us secure instead at least a more general appearance of agreement between designing engineers for the standard methods of calculation by being satisfied to apply to reinforced concrete designing the same fundamental principles of mechanics which all of us are now willing to use in the case of structural steel.

Volumes have been written on the design of reinforced concrete beams alone. Because there is no definite coefficient of elasticity for concrete, and no well-defined point which may be termed an elastic limit, certain ingenious authors have proposed a parabolic variation of fiber stress, at the same time assuming Hooke's law to hold and that plane sections before flexure remain plane afterward. Why not make the same assumptions for rolled steel beams? Steel is more ductile than concrete, and therefore has a greater range of ultimate values for the coefficient of elasticity. A great deal of scientific nonsense has been written because certain writers will insist on applying the properties of concrete, applicable near its ultimate resistance, to design formulas, which formulas should concern only working stresses, instead of adhering to figures commensurate with working stresses and not with ultimate values.

Why introduce into the design of reinforced concrete beams refinements of calculation which cannot be satisfied by practical construction? Why calculate the effective depth of a reinforced concrete beam to a hundredth of an inch, when we are lucky if the steel rods are placed in the field within half an inch of the position shown on the design drawing? Why make allowance for the effect of parabolic variation of fiber stress upon the resisting moment of compressive concrete, when such effect is within the

limits of accuracy of practical calculation? For the same reason, why consider the possible action of some of the concrete on the tensile side? The simpler we picture the stress behavior of a reinforced concrete beam, the better. The beam is the simplest of all members, yet we have succeeded in surrounding its design in reinforced concrete with an atmosphere of complexity and inconsistent refinements.

A reinforced beam, like a beam of any other material, consists essentially of three parts: 1. A compression flange; 2. A tension flange; 3. A web. The compression flange is of concrete; the tension flange of steel; the web is concrete properly reinforced by diagonal steel rods or stirrups.

I. The compression flange in customary design needs no steel; in buildings, especially floors, it is only necessary to determine where the compression flange is; that is, if building laws allow the designer to consider continuity, or, in the case of high buildings, if wind stresses may reverse the normal conditions for dead load.

II. The tension flange, in accordance with the preceding remarks, may properly neglect all of the concrete in the calculation for resisting bending moment; as in the case of the compression flange it is necessary to decide which is the tensile flange at any given section in any particular span of a structure. Prof. Mansfield Merriman has developed simple formulas (see *Transactions American Society of Civil Engineers*, Vol. lvi, p. 376) which take account of some tension in the concrete when considering bending resistance. These are most excellent formulas and are very simple. But why not neglect the tensile concrete since it is so near the neutral surface, and its stress intensity relatively so small that the resulting resisting moment thereof is properly neglected in practical calculations when compared to the resisting moment of the compressive concrete and the tensile steel?

Professor Merriman, in his article above referred to, aside from his discussion of economic proportions and economic working stresses in the steel, refers to a most important matter when he emphasizes the three fundamental equations upon which all elastic discussion must be based, and from which but three unknown quantities may be independently computed. From my experience, at least, it would appear that many practitioners fail to appreciate this fundamental matter and they often assume arbitrarily at least one more quantity than they have a right to assume, and thereby they introduce into their calculations considerable inconsistency.

Volumes have been written, starting with the researches of A. Considère, relating to the cracking of concrete on the tensile side of a reinforced beam. I have stated that in a simple treatment of beams we should neglect the effect of tensile concrete in the resisting moment. The metal reinforcement of the tensile flange, in other words, merely happens to be encased in concrete, some of which concrete forms an essential part of the web of the beam. That concrete cracks and everybody should know that it does. If the tension steel is subjected to possible corrosion or to probable weakening by the heat of a fire, then must that tension steel be protected — this is a problem of protection and can be solved.

All structural members of reinforced concrete which take computed stress, or which form essential parts of the building frame, in the opinion of the writer, must in rational design be protected by an envelope just as much and to the same extent as a structural rolled steel member doing a similar duty. Such an envelope must not take computed stresses; it must protect the main member from corrosion or fire, even though it, itself, be destroyed by heat or the action of the elements. Proper observance in design for the necessity of protecting envelopes to main reinforced concrete members would prohibit, in some instances at least, the use of reinforced concrete versus rolled steel. Its prohibition would be due to cost, or to largeness of cross section, or both. A case in point would be a main column in the lower stories of a high building constructed of reinforced concrete; such columns properly protected would often be of unsightly and prohibitory size and would cost more than equivalent built-steel columns.

III. The function of the web of a reinforced beam is to hold the two flanges apart and at the same time together in rigid unity of action so as to maintain under working loads safely and permanently the effective depth of the member. This web is of concrete, usually of rectangular cross section. We have already seen that it is apt to crack where it is found on the tension side of the neutral surface; such cracks are produced mainly by the tensile fiber stresses, in which consideration the action of the concrete is neglected. The web concrete, however, in addition, must withstand other important stresses which cannot be neglected. The web concrete must withstand at all sections of the beam the maximum intensity of transverse shear and the equal maximum intensity of longitudinal shear: it must also be able to take the maximum diagonal tension. All three of these

quantities are maxima at the neutral surface, and absolute maxima at the abutments.

The diagonal compression, of equal intensity at the neutral surface to the diagonal tension and approximately numerically equal to three halves of the average shear intensity at any given section, need not be considered in discussing the web strengths of beams. It will be found that beams otherwise properly proportioned can safely resist diagonal compression.

I have already insinuated, and it is thoroughly well known, that the intensities of the transverse and longitudinal shears and diagonal tension are equal at the neutral surface, each being approximately three halves of the average transverse external shear. To safely withstand these intensities, the web concrete near the abutments must usually be reinforced with metal. It is these web stresses which are most grossly misunderstood, improperly neglected or imperfectly provided for by our reinforced concrete experts. In fact, many of these experts probably know nothing, or have forgotten what they studied in college, about lines of principal stress in beams; and if this be true, they know very little, if anything, about those theorems of stress, principally the theorem of the ellipse of stress, upon which such analysis must be based.

It is not the purpose of the writer to consider every possible detail in this argument. Something may be said about T-beams. The principles of design for hooped columns have been well established. What we need in all these matters is uniformity and simplicity, avoidance of refinement not consistent with practical accuracy and calculations based upon sound mechanics, with an appreciation at all times of the degree of exactness of the working assumptions.

Frame Work and Calculations.

After all, the fault with reinforced concrete design is not in the application of theory so much as it is a practical matter relating to the treatment of details. Though different designers may employ different formulas and different kinds of patented bars, in the main, the resulting members, when designed by competent engineers, are entirely safe, where good workmanship and inspection are secured.

In reinforced concrete city buildings of the better type, the individual beams, floor slabs, columns, etc., are usually of intelligent and safe proportions. It is not to these component parts that criticisms can generally be applied. To be sure, in the re-

cently collapsed Bixby Hotel the columns were of inadequate design; but we cannot consider such a building as an example of good construction. It is not a building for present argument.

In the better types of buildings, in general, though their component parts are carefully designed and no criticism may be found to apply to their component beams, girders and columns, nevertheless, they are apt to be weak at joints, or, in other words, at important connections they are not properly provided with continuity of framework. Our more pretentious reinforced structures are often lacking in unified framework. There should be more regard given to continuity and stiffness of joints, as in steel frame buildings. No important part of the frame should be omitted. The columns should be continuous from floor to floor, and not be dowelled into floor slabs. There should be main floor girders, both transversely and longitudinally between columns, and there should be knee braces between these girders and the columns. None of these requirements was satisfied in the Bixby Hotel.

Again, there should be more attention paid to continuity in beams, girders and columns. In short, as in steel frame structures of the best type, the reinforced concrete building of any considerable height should and must have a well-unified, well-stiffened, rigid, yet elastic frame to which the curtain walls are attached, and upon which the floor slabs rest. Such a structure would have lateral stiffness and would be able to withstand transverse shock, wind vibration and possible earth tremors.

This argument does not imply that steel frames in general satisfy the conditions for unity of framework. There is great abuse and neglect of these principles in the ordinary steel frame construct on, and it is to be deplored that we do not find more open criticism in this regard for steel frame structures.

The writer considers reinforced concrete a most excellent material for low buildings, especially for buildings of two or three stories, where stiffness and solidity are desirable elements. Certainly a monumental effect can readily be obtained with this class of construction for theaters and hospitals, and for such buildings reinforced concrete should be especially adaptable where the height is limited to, say three stories, particularly when scientific design has been applied, where generous and safe proportions have been employed and where the best materials have been used, sound workmanship secured and inspection provided.

Tall Buildings.

But for tall, slender buildings of the skyscraper variety, say buildings over ten stories in height, the writer believes it a mistake to attempt the general use and application of reinforced concrete for the structural frame of the building. Not that a reinforced concrete edifice of small base and considerable height cannot be built safely and with a certainty of safety, but that this type of construction for towerlike skyscrapers is less worthy, or rather less adaptable than a structural steel frame clothed in properly reinforced concrete and sufficiently anchored masonry. Such masonry itself might be reinforced concrete, but the writer would just as readily advocate properly anchored reinforced brick work, high-grade terra-cotta, or cut stone. Popular taste and architectural decoration will very generally demand much use of brick, terra-cotta and stone for the curtain walls of buildings; and even in earthquake countries such material can be employed safely.

For very tall buildings in earthquake countries, we need a deep, substantial foundation, and a strong, elastic, well-knit, well-unified frame. For high buildings in San Francisco the foundation should be deep. This requirement with special emphasis should be demanded in the greater part of the business district, and particularly on the soft or made land. Where the base of a building is small compared to its height, it is my opinion that the foundation for soft-ground sites should be a unit of the slab variety; but for buildings of a broad base, individual piers are entirely right and proper, so long as they reach to considerable depth of foundation bed and insure essentially equal intensities of pressure and therefore practically equal settlement at all points in the foundation plan. The writer believes in and leans toward the use of wood piles with concrete grillage on permanently wetted sites. He would also advocate the use of structural steel; that is, rolled I-beams and channels as major reinforcements, so to speak, in deep foundation slabs of concrete, rather than the introduction as a substitute of thick slabs of concrete in which are imbedded only the ordinary plain or deformed bars of modern reinforced concrete practice.

Earthquake Stresses and Framework.

During the past six months, and especially in San Francisco engineering circles, much has been said concerning the calculation of so-called earthquake stresses in frames of structures. It is the writer's opinion that we cannot calculate the intensity of a so-called earthquake stress in a given member of a building

frame, because the earthquake forces are of indeterminate magnitude, and are brought into action to amounts directly proportionate to the degree of stiffness of a structure distorted by them. In other words, the elastic work produced by earthquake deflections, or the rupture work done by earthquake destruction, will be measured directly by the amount of resistance offered.

It has been advocated by some of our local San Francisco engineers that in tall buildings there should be a certain freedom of transverse bracing in the lower stories, so that such buildings might more readily take up, through the elasticity of their first story columns, shocks due to the motion of the ground. There is much of merit in this proposition, and our structural designers might with propriety give some study to the idea. Of course, it should not be argued that bracing should be entirely omitted from the first story; such procedure would put the building on stilts, a feature all too common in many steel frame designs of the past, a practice all too little condemned. In properly carrying out the idea of limberness in the first story, we should insure stiffness and continuity in the columns, and at the second floor framing level there should be special provision for the strength of connections between the floor girders and the main columns. In this way we should secure a well-framed box from roof to second floor level, a box resting upon and securely tied to freely vibrating vertical columns in the first story; and these columns in turn would be founded upon a deep and substantial foundation. Such a building would offer less resistance to distortion in being vibrated by an earth tremor, and the induced earthquake stresses would be so much the less harmful. The picture which I am trying to paint is a parallel to that in the fable of the oak-tree and the willow-tree. The willow tree bends to the fury of the storm, while the strong and stiff oak is cracked and rent.

You must notice that there is in this argument an idea entirely apart from the elasticity of the component materials. It is the idea of so designing the framework that it as a unit may yield in its elasticity, and prohibit the calling forth by its resistance of an unlimited force or energy from nature's storehouse.

This brings me to an important observation bearing, in my judgment, upon the use of structural steel versus reinforced concrete for the frames of tall buildings of relatively small base. Let us grant that both types of material in themselves have considerable elasticity. Let us grant also that provision can be made in the designing of framework for both to insure that yielding of structure which we have argued is desirable in buildings, especially in their first story columns; then that type of material

is most desirable for an earthquake country which can yield most. Unquestionably, in my mind, the high structural steel frame building can be made to satisfy the requirement most nearly in the present stages of the art of engineering science and of architectural art.

For lower structures, where solidity is required, structures from three to four stories in height, there is a lesser tendency to destructive vibration than in tall buildings. Here a reinforced concrete framed building, as one feasible solution of the problem, is heartily recommended because it can be built with integrity and rigidity of frame. Surely it would not crack to pieces and fall into a heap of rubbish as many buildings of the brick-wood combination did in San Francisco and vicinity last April. But the reinforced concrete building must not be assumed to be the only good solution for the solidly built structure of relatively low height. A structural steel frame, it must be observed, would do no harm even in a concrete theater or a concrete hospital.

In our important high structures we need, first and foremost, a solid foundation and a wiry, elastic, stiff-jointed frame; of second but no less great importance we require floors and enveloping walls of masonry properly reinforced and securely anchored to the skeleton frame of the building.

The skyscraper is still a new problem for the architectural designer. For such a structure must be developed a scheme of its own. A new architectural order, so to speak, must be created, an order of design which will be in harmony of expression with the engineering skeleton which gives the backbone of stability to the form. For tall buildings, reinforced concrete, in the judgment of the writer, will play an important part in future architectural and structural treatments, but we must be careful to observe that structural steel, especially for the building frame, demands at least equal consideration. A logical combination of rolled steel and reinforced concrete, it is believed, will affect the architectural treatment of skyscrapers in the immediate future, and will influence the architect's decorative treatment.

Architects must learn to appreciate that a heavy masonry envelope on a high framed building, in which much steel is employed, is bad engineering. They must be taught that in earthquake countries, at least, a heavy envelope of curtain walls, consisting of brittle, unreinforced, unanchored material, is especially bad engineering. Let us hope that such procedure may be considered also improper architecture.

[NOTE.—Discussion of this paper is invited to be received by Fred. Brooks, 31 Milk Street, Boston, by April 15, 1907, for publication in a subsequent number of the JOURNAL.]

ENGINEERING WITHOUT SPECIFICATIONS.

By R. S. Colnon, Member of the Engineers' Club of St. Louis.

[Read before the Club December 19, 1906.]

When asked to respond to a toast this evening by a member of your committee, there was no accompanying blue print or a line of specification, so that I consider it a great privilege for a contractor to be allowed to address one or more engineers with no limitations whatsoever, and if what I have to say seems to be somewhat disconnected, and to cover rather a large field, you have your committee to blame.

First, I would ask the question, Why are engineers and their work not more highly appreciated by the community?

Certainly not because their work lacks commercial importance, for the members of this club probably have charge of and are directly responsible for the expenditure of more money than any like number of men in this city.

The only answer that occurs to me is the engineer's innate modesty.

Of course this should be corrected, but, unlike other artists, their managers and employers do not seem inclined to exploit their merits or abilities as is done for the other professions. For example, how much do you hear of the engineers of the Panama Canal? Rather, you are treated in the papers and magazines to a picture of a big steam shovel, with the President sitting at the end of the boom, labeled " These two will dig the canal." Some one says this is as it should be, and rather as the men who have gone quietly about their business of study and investigation and carefully planned all this work before a shovelful of dirt has been moved would have it. That would be all right if we were to consider only the reward of the engineer himself, for no one is apt to overestimate the satisfaction the engineer enjoys in the execution of any carefully considered plan, and perhaps this feeling is, at times, intensified by the fact that he alone sees and appreciates the value of his toilsome planning, and that he himself is lost sight of and left to his own selfish enjoyment.

But the harm comes later to the public and his employers when some great work is to be undertaken. The necessity for this study, investigation and toilsome planning is all forgotten and they want to see the dirt fly.

Because this work of the engineer was not thought necessary or duly appreciated by the public at large, we have just been given a fine example of how not to do it in the matter of a municipal bridge. An association of well-intentioned gentlemen, with the aid of the newspapers, without study, investigation, toilsome planning or consultation with the unimportant engineer, have presented estimates and plans (all except the location having been, I believe, determined on) to the voters of this city, which have been approved by said voters, and we are told by the great religious daily that what the public endorses is always right. It has, however, before now been determined that one thousand men can just as easily as one man reach a wrong conclusion if their information is wrong, or if, as in the above-mentioned case, they assume no information is necessary.

So I am back at the question, Who shall extol the virtues of the engineer? who exploit his achievements? and I can find none better than his own modest self.

I would have him act as his own manager. I should say that if a man has the necessary qualifications for chief engineer of the greatest canal the world has known he does not need a manager, but rather a chief clerk.

If a man is preëminent in the economical location and construction of a great railway, he ought to make a pretty fair stagger at operating same. Mr. A. M. Wellington, the man who has written most intelligently of the operation of railways, made his reputation locating and building them.

I would not have the engineer in his self-exploitation adopt the methods of the fakir; I would have him tell the truth, but tell it first. Don't always wait till some one comes for an opinion. I would have him take the initiative, be something of a promoter De Lesseps was the promoter of the Suez canal, but was used by others in the Panama fiasco; in other words, he allowed himself to be promoted.

Don't set up the claim to your client that you are going to buy a thousand brick or a ton of coal cheaper than any one else and that your chief claim to his consideration is your ability to prevent his being robbed by his contractor; but rather on your ability to assemble in an intelligent plan material, machines and forces such as will give economy in output, and a fee for that kind of service, however large, is small in relation to its value in the final result.

While I admit having at times tried to do a little missionary work among engineers in behalf of the much maligned contractor,

I would suggest that the engineer in furthering the interests of his own business attempt a little missionary work among contractors to the end that the contractor come to see the wisdom of looking upon the interests of the engineer and his client as his interests; which relation, if it could be brought about, would help to relieve the engineer largely of police duties and would enable him to point out to his client the excellent service his contractor was giving him, rather than have all his time taken up watching the contractor, thereby convincing his client that he was being robbed and perhaps making him suspect his engineer of being a partner in the robbery.

Don't ever try to throw dust in the eyes of your client or hide behind scientific jargon; in other words, don't make explanations and claims to him in terms you know he does not understand, for if you have blundered he is bound to see the result in your work, and whenever he hears these terms repeated he shies, and his definition of an engineer is apt to become one using strange terms of a science which applied ends in disaster.

Engineers are too apt to play the part of Phocion, who, when sent on an important mission to the Macedonians, simply made his statement of the matter and refused to say more, but left the orators to wrangle over terms; yet Carlyle says he was as effective as Demosthenes. But Phocion was compelled to drink of the poisoned cup and Demosthenes was spared. To be sure, they erected a monument to him later.

I would say in conclusion that to-day in this republic the engineer should not forget that human nature is a part of nature, and while you may eliminate the error of personal equation in mathematical discussions, it is, nevertheless, a great error to try to eliminate the personal and the human in the embodiment in brick and mortar of any of their theorems. My apology for my attachment to the cause of the engineer is that of Sancho Panza when it was said of him: " Since Don Quixote is a fool and madman, yet Sancho, his squire, who knows it, follows him and relies on his vain promises, must be more mad and stupid than his master." Sancho says: " I know it's true, and had I been wise I should have left my master long ere now, but such was my lot and such my evil errantry, follow him I must; we are of the same town. I have eaten his bread; I love him; he returns my kindness; he gave me his ass colts and, above all, I am faithful."

[NOTE.— Discussion of this paper is invited to be received by Fred. Brooks, 31 Milk Street, Boston, by April 15, 1907, for publication in a subsequent number of the JOURNAL.]

"FOURTEEN FEET THROUGH THE VALLEY."

By Harry B. Hawes.*

[Read before the Engineers' Club of St. Louis, December 19, 1906.]

"Fourteen Feet through the Valley" means a 14-ft. waterway from the Great Lakes to the Gulf.

It means increased facilities for transporting freight and the consequent saving of hundreds of millions of dollars to both producers and consumers.

It means a natural, God-made regulator of freight rates for the entire country.

It means the increased value of land and its products for the Mississippi Valley by securing new markets and more direct transportation at cheapened cost.

It means immediate facilities for trade with the Orient and South American republics, which will place the people of the Mississippi Valley on a competing basis with the Atlantic and Pacific seaboard states.

It means the reduction of the transportation tax which is paid by all our people.

It means that St. Louis will become the greatest inland city in the world.

The Valley.

Our portion of the valley spreads broadly between two mountain chains, rising gradually as we travel north less than 1 000 ft. in 1 000 miles.

With a temperate climate, it forms the most wonderful territory in the world; with natural resources unsurpassed, it is only beginning to develop by the arts of man.

A competent authority has, perhaps, summed up its physical perfections in saying that it can support from 400 000 000 to 500 000 000 people and carry on trade with as many more when it has reached the Old World density of population.

Water power is to-day the greatest of its undeveloped resources.

Through its center for a distance of 3 160 miles flows the Mississippi River, whose great eastern tributary, the Ohio,

* Chairman of the Speakers' Committee of the Lakes to the Gulf Deep Waterway Association.

reaches a distance of 975 miles to the Alleghanies, and the Missouri extends west to the Rockies a distance of 2 575 miles.

It would test your patience and confuse you to name all the navigable rivers emptying into the great trunk stream; it will suffice to say that in the valley 15 000 miles of navigable streams exist.

Each navigable stream means a transportation highway; each new highway will help just so much to remove freight congestion and lower the cost of its moving.

Freight Congestion.

Mr. James J. Hill, the railroad expert, has said that in the last ten years the growth in ton mileage was 110 per cent., whereas the growth of railroad mileage in the same period to handle the traffic was only 20 per cent. Continuing he said:

"The traffic of the country is congested beyond imagination. The commerce of the country is paralyzed, and continued, it means slow death.

"More cars? Yes, we need more cars, but we need also cars of greater capacity, heavier trains and more miles of railroad to haul them over. In ten years the railroads of the country expanded 20 per cent. for the handling of a business that increased 110 per cent. Suppose you are able in the near future to increase that expansion 50 per cent? That will still leave 40 per cent. a year of the business without any facilities for taking care of it.

"It is estimated that from 115 000 to 120 000 miles of track must be built at once to take care of this immense business. But to build that amount will cost as much as the Civil War cost, at least. It will cost from $4 000 000 000 to $5 000 000 000. A thousand millions of dollars a year for five years will scarcely suffice. Why, there is not money enough nor rails enough in all the world to do this thing!

"And if the rails were piled up ready for the undertaking, and if the money were in bank to-day, it would be impossible to get the labor with which to do it.

"I tell you, there is no question since the Civil War of half the consequence of this one. Why, you can't go out and contract with any railroad in this country to move 500 cars of freight from here to New York in thirty days. And the railroad could not deliver if it should contract to do it.

"The great cry is that there are not cars enough. The trouble is that you can't put cars on the track and get half the movement out of them that you could ten years ago. Statistics show that freight cars running from 12 to 15 miles an hour average a movement of 25 miles in 24 hours. Think of it — only 2 hours a day in operation! Is there any business in the world that can sustain itself when its equipment is in use only one twelfth of the time?"

Such facts and figures coming from such well-accepted authority astound us.

This congestion, which paralyzes trade and affects the pockets of all, can be removed by a proper regulation of our waterways.

We have in the Mississippi Valley 15 000 miles of natural waterways requiring regulation alone to become serviceable for this purpose.

Who Is Responsible?

The natural questions, then, are, Why have they not been regulated? and, Who is primarily responsible for such apparent, almost criminal, neglect?

First, there has been a lack of intelligent, persistent and systematic effort upon the part of business men in educating the people to the possibilities and benefits of this work.

Second, the transportation question has not been, until recently, understood to affect every man alike in all walks of life; the average citizen did not know that he paid a transportation tax and that he had some voice in the regulation of rates and in stopping discriminating rebates.

Third, Congress, which is ready and willing to follow an enlightened public sentiment in favor of any great public enterprise, has refused to make adequate appropriations necessary for this purpose in the absence of clearly expressed public sentiment favoring it.

This leads us finally to place the blame where it properly belongs, not upon the national government, but upon our people for not making a determined demand, backed by a compelling public sentiment favoring necessary appropriations for river regulation.

At present there is no party politics in the demand for an adequate appropriation; there should not even be a sectional question raised; for, while the Mississippi Valley will make the demand, second thought will lead the whole nation to believe that it is a national, not a sectional, issue.

While we know that the question is national, and will avoid a sectional issue if possible, yet, if it must come, certainly we feel assured that a properly expressed demand made upon Congress by our representatives from the Mississippi Valley will not fail.

After public sentiment is aroused, and an intelligent plan proposed, we will soon learn to pick our friends from our opponents; we can then both reward and punish without injustice.

A Special Plan.

It is not enough that a general plan of deep waterways and the improvement and regulation of navigable streams should be advocated, but some special, exact and detailed plan must be presented first to the people and then to Congress.

Acting on this theory, an organization was formed in St. Louis last month having for its object a specific plan, a 14-ft. channel from Lake Michigan through the Mississippi River to the Gulf. This is intended only as a trunk waterway and is in no sense of the word antagonistic, but, on the contrary, upon completion, will be the strongest argument in favor of the regulation of all the tributaries of the Mississippi. Just as it would be unwise to attempt to build artificial waterway tributaries first and the trunk last, or attempt to build tributaries of a railroad first and the trunk line last, so it would be the height of folly not to concentrate, at least for the time being, on the trunk waterway. Our engineers, as well as Congress, must have some definite plan. We now have that definite plan, and it will be but a short time before all of its advantages will become known.

The Divide Removed.

Scientists tell us that at one time the opening of the Great Lakes was to the south, and that Lake Michigan spilled its surplus water into the Mississippi River. Nature, for some cause, changed the course of this outlet so that this water now flows through the Niagara.

When Joliet, in 1673, reached the Chicago divide from the lake side, he was shown by his Indian guide how to portage and take the river route to the great sea. He probably was the first white man to suggest the lakes to the Gulf waterway.

When Nature changed the outlet of the Great Lakes, she added greatly to the picturesqueness of our country by the creation of Niagara Falls, but she closed the old channel by a rock obstruction only 30 ft. higher than the present outlet. The city of Chicago, at a cost of $50 000 000, has again opened the old channel by cutting away the divide and letting the water of the lakes flow into the Illinois and thence to the Mississippi; so that a number of pleasure parties have started from Gulf ports, skirted the Gulf shore, rounded Florida, followed the coast line of the Atlantic, passed through the Great Lakes, down the Illinois to the Mississippi and stopped to visit us at St. Louis on their way to New Orleans.

Chicago now proposes to give its ship canal, which it secured at a cost of $50 000 000, to the national government, provided the government will complete the work from Lockport to the Mississippi. The present Congress will be asked for an appropriation of $3 000 000 to complete the channel from Lockport to Joliet, and the estimate of the remaining cost of a 14-ft. ship canal from Chicago to St. Louis is $32 000 000.

It is believed that the work can be completed in ten years, and be finished before the completion of the Panama Canal.

Not a New Project.

This is not a new project. In 1808 Albert Gallatin, then Secretary of the Treasury, in a report to Congress, advocated the construction of a ship canal across the divide along exactly the same line as that adopted by the city of Chicago. It has been overshadowed, however, by questions seemingly of more immediate concern. Conditions have changed, and to-day the paramount question before the American people is undoubtedly that of transportation. The leaders of both political parties are demanding that something be done. The intelligent thought of the nation is directed to a solution of this question, and, naturally enough, water transportation is, for the first time, receiving that consideration which its importance justifies.

In Europe.

An examination of the subject has taken some of our experts to Europe, where they find that Holland, Belgium, France and Germany have a waterway development of 18 920 miles in a land area of 449 000 sq. miles, or 1 mile of waterway for each 23.2 sq. miles of territory. France has about 1 mile to 26 sq. miles, and Germany 1 to 29 and still expanding, while Holland and Belgium together have 1 mile of waterway to each 6 miles of territory.

We find the Mississippi Valley has 1 725 000 sq. miles and 15 000 miles of natural waterways capable of being expanded as development requires to 25 000 miles, all at the present time neglected by the government, of practically little use to our people and the cause of millions of dollars of damages to our Southern planters by reason of overflows and floods.

In 1896, Mr. Burton, chairman of the House Committee on Rivers and Harbors, said the United States had expended, since the formation of the government, for rivers, harbors and waterways of every description, a little over $273 000 000, while

France had, in eighty years, expended for the same purposes $706 000 000. And yet a single state of this Union has a larger area than all France.

France has nearly 2 500 miles of waterway and 3 000 miles of canals. Germany has 10 000 miles of navigable waterways, with about 3 000 miles of canals. The British Isles have 8 000 miles of canals, four of these alone costing $377 000 000. Even Ireland has 16 waterways, covering a distance of 749 miles.

Why All Valley Streams Meet near St. Louis.

Mr. Cooley, in discussing our proposed waterway, calls attention to a significant feature of the Valley of especial interest to St. Louis:

"In the extension of low levels well north in the geographical heart of latitude 42 degrees, between meridians 87 and 92, Illinois is the lowest state north of the Gulf margin, having an average altitude of only 632 ft. above sea level, being 100 ft. lower than Indiana, 300 ft. lower than Michigan, 450 ft. lower than Wisconsin, 500 ft. lower than Iowa and 200 ft. lower than Missouri; lower even than Arkansas, Kentucky and Tennessee. This might have been inferred, for all the waters gravitate to her shores. The Missouri, the upper Mississippi, the Wabash, the Ohio, the Cumberland and the Tennessee, and all the water routes from the north land and the Great Lakes touch her borders. Such a condition carries a mild climate well north, and makes possible navigation in ordinary winters up to latitude 40 degrees at Chicago and Clinton."

Railroads Not Hostile.

It has usually been supposed, and may probably be true, that the great influence which railroads have unfortunately exerted upon our national law-making body has been hostile to large appropriations for the river. The expressions now given by leading railroad men exhibit a more liberal view, and we find no apparent hostility. This is due to the fact that railroad service, as at present constituted, is totally incapable of promptly moving our great crops and heavy freight at certain seasons of the year, resulting in a congestion entailing enormous loss to the farmer as well as to the manufacturer and consumer. It is interestingly said that,

"Some 35 per cent. of the freight moved by the railways of the United States, bituminous coal and other minerals, are worth less than $1 per ton where produced; 17 per cent., anthracite coal, coke, iron ore and other products, are worth less than $2; and still another 12 per cent., coarse manufactures

like brick, cement and lime and wood, logs, etc., are worth less than $5 per ton. The consumer has only to consult his purchase price to know that railway transportation is by far the largest element in the cost of more than half the commodities that seek a market."

It will be freight of this kind that will be largely handled by water transportation. The railroads will have their monopoly of fast transportation, the connection between waterways and the haul to the waterways. They will, therefore, probably be content with this share of the business, especially as it will carry with it the transportation of all perishable goods and passengers.

Remembering what Mr. Hill has said, there seems to be no great reason why railroad influences at Washington should be antagonistic.

Railroad Regulation.

It is true, though, that river regulation will mean rate regulation and the competition will hurt.

Mr. M. C. Markham, traffic expert, showing the influence of the Mississippi River on railroad rates, said:

"The river, as can be readily understood, makes the rate from St. Louis to New Orleans. The railroads running between those points, to get a share of the traffic, must necessarily offer rates approximating those of the river craft. Chicago is not situated upon the river, but it would be put to a disadvantage as regards the Memphis or New Orleans trade if it were not put upon a relatively fair rate plane with St. Louis.

"By way of illustration: When the rate on wheat from St. Louis to New Orleans by river was 30.6 cents per bush., it was 70.2 cents per bush. by rail from St. Louis to New York. In thirty-five years the river rate fell from 30.6 cents to 4.25 cents per bush. to New Orleans, and the rate by rail to New York followed it down from 70.2 cents to 11.6 cents."

It is scarcely necessary to give illustrations of this kind. Competition means reduction in price in transportation as well as in trade.

The average cost of carrying a ton of freight, in 1904, by rail was 7.8 mills per mile. This was the average, but on the Illinois Central, which parallels in many places the Mississippi River, the rate was 6 mills per ton per mile.

The cost of transporting freight on the Ohio River was 0.76 mills per ton per mile.

The cost of transporting freight from Cairo to New Orleans was 6 to 7 mills per ton per mile, and the cost of transporting

freight through the Sault Ste. Marie canal in 1905 was 0.85 mills per ton per mile.

The cost, therefore, on three great waterways was considerably less than 1 mill per ton per mile, as compared with 7.8 mills per ton per mile on the railroads, making the relative cost of transportation by rail and by water 6 to 1 in favor of water transportation.

These scattering illustrations of the difference in cost between water and rail transportation, even coming as they do from high authority, are not entirely satisfactory. But they furnish the indisputable proof of the cheapness of water transportation as compared with that by rail.

The Government's Duty.

Early in the country's history the government assumed ownership and control over our navigable waters, and to-day it is the sovereign controlling power of all navigable waters. Having assumed this power, it is the duty of the government to exercise it vigorously for the benefit of all the people. It cannot escape responsibility for, or dispossess itself of, the slightest control over any navigable water without express permission of Congress, which that body has in the past very properly refused.

A delegation of St. Louisans appeared before the chairman of the Rivers and Harbors Committee and asked for an annual appropriation of $50 000 000. Mr. Burton seemed to think that a large amount. Mr. Edward Goltra, of this city, said to him that if the national government would give him permission to regulate the river and charge toll for tonnage, he would agree to bond the enterprise for $50 000 000 within thirty days. While this statement was probably made in an argumentative way, there is, to my mind, hardly any doubt that private capital would gladly invest and find it a money-making enterprise. If it would be a good investment for private capital, why would it not be equally good for the government?

The policy of the government has been extremely shortsighted and parsimonious. While spending 63 per cent. of its total revenue for war and preparations for war, it has only expended 3.5 per cent. of its total revenues for all of its lakes, rivers and harbors.

In Case of War.

With the intention of appealing to the warlike spirit which seems to possess some of our newspapers, the novel argument

in favor of the deep waterway has been advanced that it can be used in case of war with Great Britain. By a treaty between the United States and Great Britain, no warships are permitted upon the Great Lakes. After completion of this treaty, however, Great Britain built a deep canal through her territory, connecting it with the Lakes; so that, in case of war, she could send her fighting ships into the Great Lakes with expedition and place our lake cities in jeopardy.

It is contended that we can send all of our smaller vessels through the proposed channel, and then, by removing some of the armor and heavier guns from the larger vessels, they, too, could be sent from the Gulf to the Great Lakes.

Arguments in favor of our ship canal have been based upon questions of transportation and new markets. Its use, however, in time of war probably should not be underestimated.

Engineers of Ability.

The construction and engineering work of the proposed waterway are not matters that a lawyer ought to attempt to discuss before a society of engineers. I know that we have engineers of high ability, perfectly capable of planning and executing this great work, and that its success will depend entirely upon the amount of money placed at their disposal.

Nature has determined the route and furnishes the water. The control of the water and the regulation of the route are matters exclusively within the province of engineers. It is agreed that it is a mistake to make small appropriations at long intervals, as the Mississippi is a mighty, restless power and washes away each year many thousands of dollars of incomplete and partially finished work, losing millions of dollars to the government by its lack of continuous application.

The Ransdell plan calls for a regular appropriation of not less than $50 000 000 for all harbors and rivers of the nation, which it is proposed to continue for ten years, making a total sum of $500 000 000 distributed over a period of ten years. This will be sufficient to complete not only a 14-ft. channel from Chicago to the Gulf, but will amply provide for the Missouri, Ohio and other tributary streams, as well as all other rivers and harbors.

Can Be Built in Ten Years or Less.

The main unfavorable argument is the length of time required to complete the work of construction; a vague impres-

sion exists that it will be of great benefit to the next generation, but cannot be completed in ours. This is not correct. The channel can be built in less than ten years. As soon as it is known that the government has entered upon a systematic plan, we shall find that private capital will make investments in river craft and increased river transportation will begin.

Other Theories.

There is a theory for the control of the headwaters of the Missouri by the erection of dams to hold the water at certain periods of the year and regulate its flow at others.

Another suggestion comes from the southern states for the building of canals which will take off the surplus water, serving as drainage ditches and for irrigating purposes in Texas. These and many other interesting issues will grow out of the creation of the main channel, but the few minutes I have at my disposal prevent a discussion of them.

The possibilities are so great that they naturally grasp the mind of every intelligent man who gives them consideration.

One Result.

It would be a pleasure to picture the wharves of St. Louis crowded with foreign vessels, the river filled with craft taking away our products and bringing back the things we need from other climes, to draw upon our imagination and picture St. Louis, the great inland city of the world, midway between Chicago and New Orleans, close to the mouths of the great eastern and western branches of the Mississippi, in the center of the continent, surmounted by all the blessings of nature, the business heart of the nation.

How We Can Help.

This would be a pleasant task, but the practical thing is for all of us, through our clubs and associations, to discuss and advocate the passage by Congress of suitable appropriations, to demand of our immediate representatives an earnest co-operation in this work and to secure, by correspondence, the assistance of friends.

Let us give our commendation to those congressmen and senators who assist our project and oppose the reëlection of those who do not. The ear of a congressman is acutely sensitive to the demands of his constituents. It is our duty to arouse the constituents of all our representatives in the Valley.

If this is done, it will be an easy task for them to say to the congressmen of the eastern seacoast and those of the Pacific: We want our share of the national moneys spent in the Mississippi Valley. We are in favor of improving your harbors and rivers, but we want a fair share of the nation's money spent in that portion of the country where most of the nation's support comes from.

This is not yet a partisan question. Let us strive to keep it from becoming one. Some men, by natural inclination, find difficulties in the way of all progress and magnify them. It should be the especial duty of the Engineers' Club to solve these difficulties.

[NOTE. Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by April 15, 1907, for publication in a subsequent number of the JOURNAL.]

OBITUARY.

Henry Clark.

MEMBER OF ENGINEERS' SOCIETY OF WESTERN NEW YORK.

HENRY CLARK, son of Elisha and Elizabeth (Bristol) Clark, was born in Buffalo, September 8, 1839. Died July 3, 1905.

In early life he attended public schools until about fifteen years of age.

After learning the carpenter and joiner trade he advanced himself from a foreman to the head of the building department on the Western Division of the New York Central & Hudson River Railroad. He was a prominent member of the old Volunteer Fire Department for many years, being identified with the organization known as "Truck 2."

On March 11, 1863, he was appointed second lieutenant of Company D, 6th U. S. Infantry of the Corps d'Afrique, and was assigned to Ullman's Brigade, and served with the same at Baton Rouge, Brashear City and Port Hudson until August 17, 1863, when he resigned on account of illness and a gunshot wound.

He built and operated for about four years a logging and lumber railroad between Bay City and Tawas, Mich. He erected a large number of bridges for the Niagara Bridge Works of Buffalo, N. Y., and was shop superintendent for the same for about three years.

During the last fifteen years of his life he carried out a considerable amount of contract work in the way of buildings and bridges for railroads and a variety of work for the city of Buffalo.

He was a man of strong character, a born leader, possessed the faculty of organizing and controlling men, and was full of ready resources in the face of difficulties. He was a steadfast friend, a kind husband and brother. A widow and three sisters survive him.

William R. Haven.

Member of Engineers' Society of Western New York.

William Roscoe Haven was born March 9, 1840, in Coudersport, Pa., only son of Samuel and Ann (Churchill) Haven.

He attended common schools at home until 1857, excepting one year spent at the home of his grandfather in Portsmouth, N. H., where he studied "navigation and surveying" and so learned how to find his position in the middle of an ocean or of a boundless prairie and thence to run a true course. This was the only technical schooling he had.

He began his work in civil engineering and surveying on a railroad in Wisconsin in 1857. The panics of 1857 stopped all railroad construction in the West, and he went home to Coudersport, where he was engaged in land surveying and other similar work until 1861. During this time he acted in the capacity of a "surveyor of timber," which is a business at present almost unknown; but at that time there was a large amount of pine land in the forests of Pennsylvania, and capitalists wishing to invest money in them sent men of good judgment into the forests to survey and estimate the amount of feet board measure of pine timber on certain tracts of land, often thousands of acres; and the fact that young Haven, scarcely twenty-one years of age, was appointed a "surveyor of timber" shows that even at that time he was possessed of such good judgment that capitalists reposed confidence in him.

From 1861 until 1880 Mr. Haven was employed almost constantly as a civil engineer in charge of the location and construction of railroads in the eastern as well as western states, filling positions in the engineering departments from rodman to assistant chief engineer, and in the operating department he was for a term of years division engineer and roadmaster of the Chicago, Burlington & Quincy Railroad.

As an engineer he was studious, painstaking, scientific and accurate, fertile in expedients, loyal to his employers and just towards contractors and workmen.

In 1880 Mr. Haven had increased from a rather slim youth to a size and weight that made it unpleasant for him to do the field work of a civil engineer; and he came to Buffalo and began work, that continued to the end of his days, as contractor for large works, beginning with Craigie, Rafferty & Yoemans, who had extensive contracts on the Erie and Buffalo Creek railroads, as their superintendent of construction; then in

partnership with his cousin William Haven, of Iowa, under the firm name of W. R. & W. Haven. They laid tracks in and around Buffalo for the D., L. & W. R. R.; they also built the United States Public Building in Syracuse and the shops and other terminals of the West Shore Railroad in Buffalo. In a few years William Haven withdrew from the partnership and "Rock" continued the business simply as W. R. Haven. Amongst the works constructed by him are the shops of the Wagner Palace Car Company, the shops and roundhouse of the Lehigh Valley Railway, as well as a part of the main line of this railroad, the buildings of the New York Central Railroad at Depew, and most of the buildings of the smelter works of the Calumet & Hecla Company at Black Rock.

In the later years of his life there was sharp, sometimes unscrupulous, competition amongst contractors, and "Rock" Haven was not a low bidder, but sought to get a fair price for first-class work. It has often been said of him: "'Rock' Haven understands only to do good work, and his directions were imperative to his sub-contractors as well as laborers to do good work regardless of cost"; and as a contractor he exhibited the same persistent qualities and good judgment that characterized him as a civil engineer. Such qualities corresponded to his large physical body, which was but a storehouse for the wealth and good cheer which he dispensed so freely to all his acquaintances. "Big hearted, happy man that he was, the memory of him will long linger with those who knew him."

He was a great reader and kept well informed on events old and new; his memory was such that he always remembered a face and could call a person by the right name even if they had not met for forty or more years.

He was opposed to shams of all kinds, not only of materials and constructions, but of men and women.

He had hosts of acquaintances wherever he lived, and he also had some friends.

He never found a church which seemed to be of help to him in solving the problem of his existence, and September 5, 1905, he passed on to that state where he could continue to try to solve this problem unhindered by material weights and beliefs.

In 1862 he married Narissa Wood. His wife passed away December 30, 1903; they had no children. His father, born in 1815, now lives in Coudersport, and three married sisters survive him.

He joined the Engineers' Society of Western New York, April 7, 1902.

Wallace Clyde Johnson.

Charter Member and Past President of Engineers' Society of Western New York.

Wallace Clyde Johnson, civil engineer, died at his home in Niagara Falls, N. Y., December 15, 1906, after a brief illness.

Mr. Johnson was a son of James W. and Frances Ann Johnson and was born in Granville, Mass., May 21, 1859. His education was received in the public schools of his native town, in Williams College and the Worcester Polytechnic Institute, and he was graduated from the latter in 1884 with the degree of B. S. In 1894 Williams College conferred the degree of M. A. upon Mr. Johnson, at the same time conferring special degrees upon Theodore Roosevelt and Joseph H. Choate.

For the first two years after his graduation from the Worcester Polytechnic Institute Mr. Johnson was employed as assistant engineer in the hydraulic department of the Holyoke Water Power Company, at Holyoke, Mass., where he began his professional career as an hydraulic engineer.

In 1886 Mr. Johnson accepted the position of chief engineer of the Niagara Falls Hydraulic Power and Manufacturing Company, which position he held until 1900, when he became consulting engineer for the same company.

In 1893 Mr. Johnson married Eloise Gertrude Murlless in Holyoke, Mass., and from that time they made Niagara Falls their home.

While chief engineer of the Niagara Falls Hydraulic Power and Manufacturing Company, Mr. Johnson designed and installed the first and second enlargements of that company's great hydro-electric plant, which was the pioneer plant to use turbine wheels under a head of over 200 ft., and the work was accomplished with such credit that he was called in consultation by many companies having power development or transmission problems to solve.

His consulting practice grew rapidly and to such large proportions that he maintained offices in Niagara Falls, New York City and Montreal, and he gave it his closest attention until the time of his death.

Among the many positions filled by Mr. Johnson the following are the principal ones: Chief and consulting engineer of the Niagara Falls Hydraulic Power and Manufacturing Company; chief and consulting engineer of the Shawinigan Water and

Power Company; chief and consulting engineer of the Bodwell Water Power Company, Oldtown, Me.; chief engineer of the Hannawa Falls Power Company and the Empire State Power Company; chief engineer, vice-president and general manager of the Albion Power Company; chief engineer for the reconstruction of the plant of the Chicoutimi Pulp Company; and consulting engineer for the Pittsburg Reduction Company and the Buxton Power Company.

In addition to the above-named works, Mr. Johnson has been consulted, or made examinations and reports, on numerous power projects in the United States, Canada and Nicaragua.

Besides this hydraulic work Mr. Johnson, prior to 1895, designed and superintended the construction of a system of sewers for Niagara Falls, laid out most of the new part of the city, had charge of the construction of all the electric railroads in the city, built a mill using 2 500 h.p. of water under 125 head for the Clifft Paper Company of Niagara Falls, laid out the electric railroad from Niagara Falls to Buffalo and had charge of many other smaller works.

When the state of New York instituted the State River Improvement Commission in 1904, the Governor appointed Mr. Johnson its first engineer commissioner, and when, in 1906, this commission was superseded by the State Water Supply Commission, he was retained as a member of the latter board.

At the time of his death Wallace C. Johnson was consulting engineer for four of the power companies for whom he had designed and constructed plants, and was engineer and general manager of the Albion Power Company.

Mr. Johnson was a member of the following societies and clubs: American Society of Civil Engineers, American Society of Mechanical Engineers, Canadian Society of Civil Engineers, the Engineers' Society of Western New York, American Institute of Electrical Engineers, Society of Arts, London; Niagara Frontier Historical Society, the University Club of Buffalo, the St. James Club of Montreal, and the Tarratine Club of Bangor, Me.

Wallace C. Johnson was a genial and kindly gentleman who drew to himself a host of warm friends, by whom he will be greatly missed. He was a tireless worker in his chosen profession, to which he was thoroughly devoted.

He is survived by his widow, his father and mother and one sister.

WALTER MCCULLOH, *Committee.*

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THE STRUGGLE FOR WATER IN THE GREAT CITIES OF THE UNITED STATES.

BY MARSDEN MANSON, MEMBER OF THE TECHNICAL SOCIETY OF THE PACIFIC COAST.

[Read before the Society January 4, 1907.]

THE objects of this paper are to present certain features of the great problems of municipal water supply. It is not proposed to take up, except historically, the purely structural features, as these are fully treated in technical works.

The problems to be considered are those of ownership and those requiring a change of source or expensive treatment to render an impure water suitable for use in the home. The studies incident to these changes in ownership and source involve problems in economics and civic policy which are sometimes more difficult than those concerning the development, conduction and distribution of the supply. These struggles for ownership are fought out on two lines: (1) to hold, when once in municipal control; and (2) to gain or regain when in adverse ownership. They are gradually being won by municipalities, for municipal ownership has been and is yet gaining ground. It prevails in all the cities in the United States above the 21st class except San Francisco and New Orleans, which rank 9th and 12th, respectively.

Of the fifty largest cities in the United States municipal ownership obtains in all except nine (9), as follows:

San Francisco (9th); New Orleans (12th); Indianapolis (21st); Denver (25th); New Haven (31st); Paterson (32d); Omaha (35th); Memphis (37th); and Scranton (38th).

To present the history of any considerable number of these is beyond the limits of this paper; hence a typical case of each system of ownership has been selected and the principal efforts as to ownership will be outlined.

The two cities chosen for this purpose are *New York*, owning and operating its own supply, despite strong and repeated attempts to wrest it from the municipality; and *San Francisco*, in which the privilege of water supply is yet held by a corporation, despite more than a third of a century of effort to secure municipal control. Each of these cities is the largest of its type, and a study of their struggles for the ownership of this great necessity of life and health is full of instructive lessons, not only to the civil engineer, but to all citizens.

These two types stand opposed to one another, not only in the matter of ownership, but in the objects to be attained by such ownership. Under corporation control the prime object is *profit* — what can the investment be made to yield in dividends, salaries and interest? How can the stock be doubled or trebled with the least investment of actual capital, and how can laws restricting profits to a reasonable return on this actual investment be overreached?

Under municipal ownership the prime question is, What are the lowest rates commensurate with an abundant and pure supply?

Both systems have their drawbacks and advantages. Under corporation control there is frequently the advantage of long service, high skill and no politics, so far as officers and employees are concerned, but there is a standing abuse in the corruption of those officials charged with fixing rates,* and the consequent introduction and support of " the boss " in municipal politics, with all the resultant evils.

Under municipal ownership political control too often becomes the leading motive, so as to use the officers and employees as a voting power and these positions as political rewards. Hence the control and operation shifts with victory at the polls to the detriment of the public health and to the safety of property.

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* So much has this obtained in San Francisco that a supervisor, after two terms as chairman of the Water Committee, took a tour around the world. Upon his return a shrewd Irishman, who knew the facts, remarked of him, " That is the shmartist man Oi know. He wint entoirly around the worruld on frish wather."

EPITOME OF THE HISTORY OF THE WATER SUPPLY OF NEW YORK.

In 1613 a small Dutch colony established itself on Manhattan Island. The colonists constructed a small fort and a few cabins. Water was supplied by means of wells, from which it was hoisted with ropes or balanced poles.

Water was supplied in this manner until 1658, when a public well was dug in lower Broadway. This supply, with private wells, lasted for fifteen years later, or until 1673, when additional public wells were added, bringing the total number up to nine.

By 1748, or one hundred and thirty-five years after the earliest occupancy, these wells were recognized as foul or contaminated, and much of the drinking supply was hauled from the "Old Tea Water Pump" and other sources supposed to be pure and wholesome.

The water wagons hauling from this pump so obstructed foot traffic that in 1797 the pipe was raised to permit people to walk under it.

By 1774 the population had reached the figure of 22 000, and increased water supply was attempted by the construction of reservoirs on the higher parts of the island, and pumping water into them from wells grouped around a fresh water pond known as "The Collect," situated near Leonard and Center streets. For this purpose £11 400 at 5 per cent. interest were expended. The works, consisting of this group of wells, pumps, reservoirs and bored logs for pipes, were completed in 1776. The water was insufficient and the works were soon abandoned.

In 1786 the first attempt to get control of the water supply was made by a private corporation. The town authorities were induced to call for proposals for furnishing water. The proposals were submitted, but such indignation was expressed at the action of these authorities that the proposals were returned unopened.

During the next twelve years, or until 1798, various projects were discussed. In these discussions Dr. Joseph Browne, a very broad-minded and far-seeing citizen, took the advanced position that the water supply contained "the germs of diseases," and strongly advocated bringing in water from Bronx River. He urged, in 1798, one hundred and nine years ago, that "the health of a city depends more on its water than on all the rest of its eatables and drinkables put together," a truth which the authorities at the present day cannot afford to disregard.

In February, 1799, the Bronx plan was about to be carried out. In this it was proposed to introduce 3 000 000 gal. daily, the works to be constructed and owned by the city. The necessary authority was asked of the state legislature. Instead of granting it, that body came to the remarkable conclusion that the granting of such authority to the city was "doubtful"; and, instead, granted a far more doubtful charter to certain speculative gentlemen, headed by Aaron Burr, constituting a corporation known as the "Manhattan Company." This charter conferred other rights than furnishing water. Under these rights this company entered into the banking business. They did not carry out the Bronx system which, by implication, they were obligated to do, but instead dug a well near Center and Chambers streets, constructed a reservoir and laid some 23 miles of wooden pipe. Under the charter thus obtained the great banking institution known by this company name yet maintains its charter and business as a bank by pumping water from a well in this neighborhood into a nearby stone reservoir.

In the manner above described New York was partially supplied with water until 1830.

In 1829 the city again undertook the construction of public water works by building a reservoir and pumps and laying 12-in., 10-in. and 6-in. mains therefrom, principally for fire protection.

During this period water supply was very unsatisfactory, and various attempts were made to secure the Manhattan Company's works for the city.

The city had evidently learned a lesson of import in this struggle, and, in 1830, several projects were under consideration:

(1) Rye Pond (Bronx).
(2) Croton River.
(3) Passaic River.
(4) Wells on the island.

In 1832 the ravages of cholera emphasized the importance of a pure water supply. It is instructive to review the conditions existing about that time: Water was furnished by wells, most of them polluted by an occupancy of two centuries. Yellow fever and cholera had scourged the city; the ravages of other water-borne diseases had been severe. From a quarter to a third of a million dollars per year was spent in buying water, brought from supposed uncontaminated sources, at 2 c. per gal. Brooklyn spent about $50 000 per year in the same way. Thus the price

of using impure water was paid not only in dollars and in the depreciation of property, but in the lives and health of the citizens.

Finally, in April, 1835, the proposition to bring Croton water into New York was carried by a vote of 17 330 against 5 963.

Ground was broken in May, 1837, or a little over two years later, the intervening time having been necessary to mature plans and let contracts. Water was turned into the reservoirs and mains on June 27, 1842, and in November, 1848, the high bridge over Harlem River received its finishing touches and the works were completed. The total cost was $12 000 000, and the volume of water made available from the Croton watershed of 360 sq. miles was 60 000 000 gal. per day, since forced to much more than this.

It became apparent within the next third of a century, or during the latter half of the seventies, that even this supply had become inadequate, and for some years additional sources were considered.

So rich a prize as the supplying of a vital necessity to the great metropolis of America did not fail to attract attention. So again, in 1887, a scheme was conceived to wrest the control of this supply from public ownership and put it in corporation control. In that year the Ramapo Water Company was organized, ostensibly for manufacturing and mining purposes. Subsequently this act was amended to permit this company to supply water to any municipality in the state of New York. Three years after the organization of this company was effected the general law under which it had originally been organized was repealed and immediately reënacted, throwing legal safeguards around contracts made with companies supplying water. Subsequent legislative action still further strengthened the Ramapo Water Company by conferring privileges upon it which were specifically denied the city of New York. This great municipality was still further crippled by the insertion of a clause into the charter of Greater New York by the legislature forbidding that city from taking water from a source devoted in whole or *in part* to the supply of any other municipality.

The Ramapo Water Company had not been idle on other lines. It laid claim to nearly every possible source of water in the state of New York.

Its corrupting influences were not confined to the legislature, for its officers proceeded to draw up a contract between the water commissioner and the Board of Public Improvements

of Greater New York and the Ramapo Water Company, which contract, if signed by the commissioner and approved by the Board, would give the company complete control of the New York water supply. Under the able tutelage of this company, the legislature had already passed the laws necessary to confer these powers upon the officers above named and to make their action binding upon the taxpayers of Greater New York.

To make the necessity for prompt action more apparent, the existing water supply of New York was lavishly — nay, criminally — wasted.

"On August 16, 1899, Mr. William Dalton, commissioner of water supply, presented to the Board of Public Improvements for approval a certain proposed contract between the city of New York and the Ramapo Water Company." (Pres. Wm. F. King's Report to the Merchants' Association of New York, p. 23.)

Commissioner Dalton strongly urged the adoption of the contract and was favored by a majority of the Board of Public Improvements.

Petitions were submitted to this board purporting to be in support of this contract. These petitions were signed with the names of more than a thousand firms and business men of New York. It was subsequently found out that the majority of these signatures had been fraudulently obtained or used or were spurious.

The piratical work of the buccaneers and pirates of the Spanish main was mere child's play beside the purposes and plans of the Ramapo Water Company. These purposes and plans were intended to lay the great city of New York under tribute to that company in the amount of $195 000 000 in forty years; at the end of which time the city would doubtless be more securely in its power. Fortunately, there was in the Board of Public Improvements at that time one man who temporarily blocked this nefarious scheme, until, through injunction suits, the backing given him by the Merchants' Association of New York and Governor Theodore Roosevelt, the entire plan was thwarted. That man was Mr. B. S. Coler, comptroller of the city. The result of his stand is the continued ownership of the supply by the city.

As Greater New York now stands, less than one half of 1 per cent. of the water of the boroughs of Manhattan and Bronx are supplied by a private company, the rest by the city. Ninety-three per cent. of Brooklyn is supplied by the city, the remainder by private companies. Queens is supplied largely by wells, 30

per cent. owned by the city, 70 per cent. by individuals and private corporations. Richmond yet depends upon wells, either private or by private corporations.

Steps are being taken to still further increase the Croton storage by small reservoirs and to bring in additional supplies.

The engineering works are set forth in full in the excellent reports of Freeman and Wegmann and in the reports embodied in the history of the water supply of the city of New York by the Merchants' Association. From these reports, and from several inspections of the New York works by the writer in 1875 and 1904–5, the above very brief history is compiled.

At present a commission of engineers is engaged in developing a far larger system and making studies as to purifying the supply which, under any circumstances, must be drained from populated areas.

Thus, in the history of New York's water supply, three notable attempts have been made to secure control by corporations:

The first in 1786, when the city authorities were persuaded to ask for proposals for supplying the city with water. These proposals were submitted, but the storm of protests against the proposition caused these proposals to be returned unopened.

The second attempt was made in 1799, when the glittering prize of a banking establishment was concealed in the charter granted by the legislature. The water supply was only a secondary proposition in the scheme and practically perished after some years of monopoly control.

The third attempt by the Ramapo Water Company culminated in 1899. This company succeeded in corrupting the legislature and some of the city authorities, but was defeated before consummating its purposes. This attempt was so skillfully planned, pressed with such total disregard to honesty and was ultimately so thoroughly exposed and defeated, that the capture of New York's water supply will probably never again be attempted.

Brief Outline of the History of the Water Supply of San Francisco and of the Efforts to Attain Municipal Ownership of the Same.

Upon the settling up of the peninsula in 1849–50 the necessity of a water supply was met by springs and wells at several points within the limits of the city. The soil being unpolluted,

these nearby sources were safe, but soon failed to meet the rapidly growing demand. Water was then brought from springs and streams in Marin County and distributed to homes, restaurants, hotels, shipping, etc., in buckets and casks (as is now being done).

In 1851 the Mountain Lake Water Company undertook to bring the water of Mountain Lake and Lobos Creek into the city, and made a contract with the city of date June 1, 1851. (City Manual, page 117, Ordinance No. 167.) This ordinance was amended and the time extended from time to time.

In 1857 the San Francisco Water Works was organized and succeeded in bringing in the water of Lobos Creek around the shores of Golden Gate, by tunnel through Fort Point, and flume to Black Point, where it was pumped to suitable elevations. Water was introduced on September 16, 1858.

This company and the previous one, the Mountain Lake Water Company, had numerous suits at law. The Mountain Lake Water Company failed in 1862 and went out of business.

In the meanwhile George H. Ensign organized the Spring Valley Water Works under a charter obtained from the legislature. He took up a small spring near the intersection of Mason and Washington streets and laid a few pipes in 1858. He kept this franchise alive by extensions of time until 1860, when it was bought by a stronger company. (This company retained the name of Spring Valley Water Works until 1904, when for the purpose of overreaching the state law, which limits the bond issue to the amount of stock, it doubled its capital stock so as to issue an equivalent volume in bonds. It then changed its name to Spring Valley Water Company.)

The stronger company organized in 1860 proceeded at once to actually bring in a supply from San Mateo County and introduced 2 000 000 gal. per day from Pilarcitos Creek in 1862.

Litigation. — There then existed the two companies: (1) The old San Francisco Water Works, bringing in its supply from Lobos Creek *via* Fort Point to Black Point and pumping into reservoirs and mains. (2) The reorganized Spring Valley Water Works, bringing in the gravity supply of 2 000 000 gal. per day from Pilarcitos *via* Lake Honda. There was no litigation and no trouble about water for municipal purposes. But in February, 1865, the two companies "consolidated," or the Spring Valley Water Works "bought out" the other. In 1867, or two years later, there commenced the series of litigations which have continued until the present, notably the ten years' litiga-

tion in which the city won the somewhat barren victory under the late John F. Swift, and the litigation now in progress in the United States courts, ostensibly for adjusting rates, but evidently to get a high valuation fixed for either rates or selling out.

This Lobos Creek supply continued to furnish between one and two million gallons per day until 1895, when it was abandoned. In 1901, after several dry seasons, it was reintroduced by pumping it into the Richmond district mains, but was so foul that the company was forced to abandon it a second time.

As the demand grew with increasing population and use, San Andreas, having a drainage area of 3.8 sq. miles, reinforced by the diversion of an additional square mile, was introduced.

These sources proved insufficient, and following the dry season of 1876–7 pumps were hurriedly erected and the water of Lake Merced was pumped into the previously constructed conduits, and Upper Crystal Springs dam was commenced. The history and function of this dam is interesting.

It was evidently intended to make it appear that the site of the Lower Crystal Springs dam was not needed, for it was "gradually completed" in 1890–1, or was about sixteen years in construction. In the meanwhile, Lower Crystal Springs dam was commenced, but work was not pushed, and the critical period of 1886–8 caused the introduction of the Alameda Creek supply through two 16-in. submerged pipes from Dumbarton Point to Ravenswood, whence it was pumped into the Crystal Springs main. By 1890 Lower Crystal Springs dam was raised to a sufficient height to supply water. It was subsequently raised, and under ordinary conditions brings the peninsula supply to about 20 000 000 gal. daily (exclusive of Lake Merced supply, which is of very questionable quality).

In 1887 it was necessary to go to Alameda County for an increased supply, and since that date all increased supplies have been directed to a further development of that source.

In 1901 the two 16-in. submerged pipes were supplemented by two 22-in. mains. Artesian wells were sunk in Pleasanton Valley and galleries constructed in Sunol gravel beds. These reinforcements brought the supply up to about 35 000 000 gal. per day. And to provide for a possible shortage, wells have been sunk near Ravenswood, connected with pumps, so as to drain the gravels in San Mateo and Santa Clara counties.

The "system" of supply as it now stands has been the result of a growth stimulated by two causes: (1) To meet from the most available source the increasing demand; (2) to acquire

competing properties or projects and develop or hold them as occasion has required or may require. These two causes have gone on together, and it is difficult to completely segregate the investments and developments due to each. The result is a group of individual sources linked together by interconnections of a rather complicated character, but answering to the general term "system," in which the mode of origin and development of Mrs. Stowe's character "Topsy" is suggested. The various parts have been worked into a water supply for a city of nearly a half million people and property values of over half a billion dollars in a manner both unique and original, partly the result of design and partly of force of circumstances.

The commencement of work on Lobos Creek by the Mountain Lake Water Company in 1851 was apparently done to meet the first requirement. The organization of the San Francisco Water Works in 1857 was a well-planned and successfully executed scheme to uproot the former company. The organization of the Spring Valley Water Works in 1858 was a speculative scheme pure and simple, and for two years, or until purchased by a strong company in 1860, was carried on merely to hold a franchise. In that year this franchise was purchased by a group of capitalists, who retained the name and undertook to supplant the San Francisco Water Company by introducing water from Pilarcitos Creek in San Mateo County. This was done two years later, in 1862.

Until 1865, when the Mountain Lake Water Works succumbed and were bought out by the Spring Valley Water Works, there was competition in the supply and peace in municipal circles. But only two years later, or in 1867, litigations began, and there has been practically no peace since, the most quiet times being instances of "armed neutrality" on each side, with "system," intrenchments and heaviest guns on the side of the monopoly, and disorganized and unsustained effort on the side of municipal ownership.

But in this struggle, the greatest of its kind in the water supply of American cities, and extending over a third of a century, the city has frequently attempted to gain ownership of its water supply. The history of these attempts will now be briefly reviewed:

The first investigations of the water supply, conducted by the city with a view to municipal control, were made in 1871–2. The dry seasons, 1869–70 and 1870–71, emphasized the necessity of an increased supply, and on April 10, 1871, the Board of

Supervisors appointed a special committee on water supplies to investigate and report on the subject. This committee consulted Gen. B. S. Alexander, Corps of Engineers, U. S. A., and Prof. George Davidson, U. S. Coast Survey, and reported, December 11, 1871 (Mun. Rep., 1871–2, p. 626 *et seq.*), "that the water sources of the peninsula, within reasonable distance, are amply sufficient to furnish an abundant supply of good, pure, fresh water to provide for the wants of San Francisco for at least fifty years." *

Also, "that the city should own and have absolute control of the water works is a fact self-evident, and requires no favorable argument from us. The success and admirable management of the great water works of New York, Boston, Philadelphia, Chicago, Washington and other large cities in our own land afford satisfactory experience ample to vindicate its necessity and expediency in our own case."

General Alexander concluded, upon the basis of yield of Pilarcitos watershed, that from the 60 sq. miles on the west slope of the peninsula drainage, 20 244 000 000 gal. could be developed, which, with the yield of Canada de Raymundo, could be raised to 21 979 000 000 gal., or a daily supply of 60 216 434 gal. But he did not point out reservoir capacity for such a supply.

Professor Davidson, who in 1869 had been called upon to report upon the supply of the then San Francisco Water Company, confirmed the conclusions he had then reached, namely, that the peninsula supply was sufficient for 1 000 000 inhabitants.

These plans involved a storm water canal along the west slope of the peninsula, a tunnel through the ridge and storage capacity far beyond any yet developed. The succeeding season, 1871–2, was exceedingly wet and no action was taken upon this report.

The seasonal rainfall of 1872–3 again fell far below the average, and the subject of municipal ownership was again agitated. This resulted in the misdirected and unfortunate steps taken in 1874–5, when the city undertook the "Scowden Surveys." During these years Blue Lakes in the Sierra, Clear Lake, Calaveras Creek and the peninsula sources were surveyed and examined. The resulting report and recommendation favored the acquisition by the city of Calaveras Creek, draining

* Yet in 1887, or fifteen years later, an additional supply was introduced from beyond the peninsula, or from Alameda Creek via the Dunbarton Point submarine pipes, as previously recited.

the northwest slopes of Mount Hamilton and adjacent outliers to the north and forming the principal tributary of Alameda Creek, and subsequently known as "the Calaveras cow-pasture scheme." Despite the rather flat and cold reception of this recommendation, the city was negotiating for the purchase of the alleged rights from the proponents of this scheme when the Spring Valley Water Works, fearing competition, forestalled the city's action by the purchase of these rights and properties in May, 1875. (Mun. Rep., 1874–5, p. 684.) The moves in this scheme appear to have been planned to force the sale of these properties, either to the city, as a source, competing with the Spring Valley Water Works, or to this company, to prevent competition. This latter result was accomplished. Since 1875 these properties have been held as an undeveloped resource of the Spring Valley Water Works, or its successor, the Spring Valley Water Company, although brought forward from time to time as about to be developed.

The sale above mentioned effectually put a stop to the proposed acquisition of municipal water works, and the very wet season of 1875–6 quenched still further the feeble embers of this attempt.

But varying climatic conditions seem to affect the moods of San Francisco as to water supply, and the dry season of 1876-7 severely taxed the then existing supplies and again caused hurried efforts to be put forth by the Spring Valley Water Works to meet the demand. The city again, and on far broader lines, undertook to investigate the possibilities of existing and auxiliary sources.

In 1876–7 there was conducted a series of surveys and examinations under the late Col. George H. Mendell, Corps Engineers, U. S. A., embracing all the sources which had been brought forward up to that time, and several additional ones. Offers of these were made to the city, as well as of the Spring Valley sources and properties. The sources examined were:

(1) Existing supplies and undeveloped sources claimed by the Spring Valley Water Works.

(2) Clear Lake.

(3) Lake Tahoe.

(4) El Dorado Water and Deep Gravel Mining Company's water properties and rights. (South fork of American River.)

(5) Blue Lakes. (Mokelumne River.)

(6) Mt. Gregory Water and Mining Company. Rubicon River. (South fork of middle fork of American River.)

(7) San Joaquin and San Francisco Water Works.
(8) Feather River Water Company.
(9) Lake Merced. (Donahue, Sharp & Mahoney.)

The Spring Valley Water Works offered its properties for $16 000 000. The city made a counter offer of $11 000 000, which was declined. The proposition of municipal ownership was defeated by the proprietors of certain newspapers, who demanded that they be paid for advocating the purchase. The city then proposed to carry out the Blue Lakes scheme, but abundant rains and the completion of Upper Crystal Springs dam in the immediately succeeding years diverted public attention from the matter, not again to be taken up until the dry season, 1897–8, and succeeding seasons of deficient rainfall, and by the charter provision making it obligatory upon the supervisors to make attempts every two years to acquire this necessity.

The charter went into effect on January 8, 1900. During that year and the succeeding one the Board of Supervisors caused to be made by the Board of Public Works and the City Engineer an exhaustive study of the whole subject, taking into consideration all available sources of supply and the future needs of the city. These examinations and studies embraced:

(1) The Spring Valley Water Works' Supplies.
  (*a*) Lobos Creek.
  (*b*) Lake Merced.
  (*c*) Pilarcitos.
  (*d*) San Andreas and Crystal Springs.
  (*e*) Portola.
  (*f*) San Gregorio and west slope drainage.
  (*g*) Alameda Creek.
  (*h*) Pleasanton wells.
  (*i*) Sunol gravels.
  (*j*) Calaveras Creek.
  (*k*) San Antonio Creek.
(2) Lake Tahoe.
(3) Yuba River.
(4) Feather River.
(5) American River.
(6) Sacramento River.
(7) Eel River.
(8) Cache Creek (Clear Lake).
(9) San Joaquin River.
(10) Stanislaus River

(11) Mokelumne River.
(12) Tuolomne River.
(13) Bay Shore gravels.
(14) Bay Cities Water Company's resources.

The result was that the Tuolumne River, draining 1 501 sq. miles of the west slopes of the Sierra Nevada mountains, receiving a mean annual rainfall of 20 to 50 in., and having a mean annual runoff of about 24 in., or nearly 2 000 000 acre-ft., was selected. This source presents the following unrivalled advantages:

First. Absolute purity by reason of the uninhabitable character of the entire watershed tributary to the reservoirs and largely within a forest reservation.

Second. Abundance, far beyond possible future demands for all purposes.

Third. Largest and most numerous sites for storage.

Fourth. Freedom from complicating "water rights."

Fifth. Power possibilities outside the reservation.

It has the drawback of distance to overcome, requiring the construction of conduits aggregating 142 miles in length. But considering the partial pollution and the rapid rate of pollution to which all other sources may in the future be subjected, particularly nearby sources, the Tuolumne River is far superior to any other.* There is, however, one almost insurmountable obstacle. There are no private interests to be served by the acquisition and development of this source.

The reservoir sites filed upon are: (1) Hetch Hetchy, on Tuolumne River, developing, with a dam 150 ft. high, 89 000 000 gal. per day for the year without drawing on the discharge of the river at the intake of the canal; and, 135 000 000 gal. per day by drawing on the river when its discharge is above the possible limits of future draughts. The tributary drainage area is 452 sq. miles, varying from 5 000 to 13 000 ft., uninhabitable and presenting throughout ideal conditions of purity; (2) Lake Eleanor, on the creek of same name, and developing 57 000 000 gal. per day for seven months of the year. The tributary area is from 4 700 to 12 000 ft. in elevation and 84

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* The engineers reaching this decision had a combined personal and professional knowledge of the available sources aggregating more than one hundred years, and no well-informed and unprejudiced member of the profession has as yet even partially investigated the subject without endorsing the wisdom and soundness of the selection.

sq. miles in extent, uninhabitable and presenting likewise ideal conditions of purity. An additional area of 103 sq. miles from Cherry River and of the same character can readily be made tributary to Lake Eleanor, and its storage greatly increased by a higher dam.

There are thus over 630 sq. miles of the most ideal catchment areas tributary to these matchless reservoirs, and the capacities of these reservoirs are capable of being doubled by dams well within the possibilities of the sites and tributary areas. Moreover, the discharges from these areas are far in excess of the maximum capacities of the reservoirs, and other excellent reservoirs are available throughout the drainage area for such other industries as future needs may require. Under maximum reservoir development there must still be a large waste from the Tuolumne watershed.

The two reservoir sites necessary to utilize a portion of the waste flood waters from this source were surveyed, filed upon and application for the necessary rights made to the Department of the Interior. These rights, by reason of the lack of a precedent, were not applied for in the name of the city, but in that of its mayor, who transferred them to the city. It was considered necessary to make these surveys "surreptitiously," but the laws and regulations controlling the mode and time of making them were complied with. If it had been known that the city authorities looked to the waste waters of Tuolumne River as a source of supply, the legalized blackmail of a prior applicant or appropriator would have been put in force; as these can move more rapidly than the city, trammelled as it is by the requirements of the charter and laws. As the result, these rights were filed upon without further cost to the city than those imposed by law.*

These rights were denied by the Secretary of the Interior on January 20, 1903. He later granted a rehearing, and again denied them December 22, 1903, alleging that the law of October 1, 1901, did not authorize such grant and suggesting an appeal to Congress.

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* Since these filings were made, some five or six "locations" and "filings" have been made by private parties and corporations looking most probably to the time when this city or some one else will have to "buy them off." But if the city's applications be granted, no other rights, either prior or subsequent to April, 1902, will have to be acquired. Only rights of way for pipes and small properties within the reservoir space will have to be acquired.

Strong opposition was put forward to the granting of these rights, notably by the Spring Valley Water Company, which sent its Chief Engineer on to Washington, and he obtained an audience with the Secretary of the Interior and appeared in opposition to the application of the city before its officers were apprised of such audience and prior to the date set for the re-hearing. This company also, through and by the same officer, worked up a strong opposition in Modesto and Turlock irrigation districts, making extravagant and false representations to the landowners of these districts, some of whom, under his able tutelage, have made and published statements to the effect that San Francisco's utilization of waste water from this source "would ruin their homes and farms and convert them into deserts."

When it is considered that these districts aggregate 402 sq. miles and that the mean annual run-off of 2 ft. from 1 501 sq. miles would cover the districts with between 3 and 4 ft. of water, in addition to the 12 in. they generally receive, and that no possible development could economically make use of the above run-off, the unreasonable and false character of these objections is manifest.

Upon the denial of these rights in December, 1903, a bill was drafted and introduced in Congress and referred to the Committee on Public Lands. This bill and its sponsors, the representatives from San Francisco, could get no standing before this committee.

The city authorities, not satisfied with the ruling of the Secretary of the Interior, presented the matter to the President in February, 1905. He, not knowing the complications of San Francisco water matters, unfortunately referred the matter to the Hon. the Secretary of Commerce and Labor. That official rendered an opinion which, for illogical conclusion, will stand as a shining example. He completely overthrows the basis upon which the Secretary of the Interior founds his denials, but expresses his concurrence in and justifies such denial. The city and county attorney, still dissatisfied with this opinion, caused the matter to be again brought to the attention of the President, who furnished the city and county's representative with copies of the correspondence and requested that the argument for the city be presented in such form that it could be referred to the Attorney General of the United States.

On July 27, 1905, an elaborate statement and argument for the city was placed in the hands of the President; but one

of the secretaries, not knowing the exact nature of the paper, again referred it to the Secretary of the Interior. Upon having attention called to this error, the paper was recalled and referred to the Attorney General.

On October 28, 1905, that official rendered an opinion in which he advises the President as follows. He quotes the law of February 15, 1901 (31 Stat. 790), providing for rights of way through certain parks:

" 'That the Secretary of the Interior be authorized and empowered, under general regulations to be fixed by him, to permit the use of rights of way through the public lands, Yosemite, Sequoia and General Grant national parks, California, for . . . canals . . . *reservoirs* for . . . the supplying of water for domestic, public or any beneficial uses.'

"I have carefully considered the language of the act as above quoted and am clearly of the opinion that Congress thereby intended to vest in the Secretary a discretionary authority to grant or refuse applications of this kind.

"I would, therefore, respectfully suggest that, if you desire further consideration or different action, the matter may be taken up with the Secretary of the Interior."

No notice, so far as the writer is aware, was furnished to the city or its advocates of this letter until it was unearthed by Mr. James C. Hooe, of Washington, at the request of Hon. James D. Phelan, during April, 1906.

Between the decision of the Attorney General of the United States that the existing law of February 15, 1901, was adequate, and the publicity of this opinion in May, 1906, the Board of Supervisors passed Resolution No. 6949 of January 24, 1906. This was at once seized upon by Mr. J. C. Needham, congressman from the sixth district of California, who represented to the Secretary of the Interior that Resolution No. 6949 was an abandonment of San Francisco's rights under the application of April, 1902. This was denied by the Board of Supervisors, but subsequent actions proved this denial to be merely a subterfuge.

The history of steps lately taken is so fresh in the minds of the public that but a brief reference to it is necessary.

The Board of Supervisors in the beginning of 1906 practically had before them the whole subject. A New York promoter, Mr. Cragin, offered as an auxiliary source to the existing supply El Dorado Deep Gravel and Water Company's properties on the south fork of American River, reinforced by the stored

water of Echo Lakes, diverted by tunnel from Lake Tahoe drainage basin. The offer was for $35 000 000 and included the present source (whether by authority or not is not known to the writer).

This offer was not definitely considered. The Bay Cities Water Company, which had previously submitted a project to supply water from the slopes adjacent to Santa Clara Valley, then submitted a proposition embracing the South Fork properties of the El Dorado Company and certain rights to reservoirs and claims on Cosumnes River. This proposition was reported upon by the City Engineer in July, 1906. From his unpublished report the following is summarized:

The sources offered are of two characters:

(1) The stored and flood waters from Silver Fork, Slippery Ford Fork, Silver Lake and Echo Lakes; pure and desirable waters now in use in and around Placerville.

(2) Stored and flood waters of Sly Park and Buck's Bar, reservoirs draining from inferior areas, large fractions of which are in private ownership.

The total drainage areas on the South Fork are 243.5 sq. miles, of which only 44 sq. miles are tributary to storage within its basin. The run-off from the remaining 200 sq. miles must be diverted by canal and tunnel between 18 and 19 miles long into the drainage basin of Cosumnes River for storage. It is manifest that a large portion of the run-off thus proposed to be utilized must be lost, as a mountain canal to divert the maximum discharge is not reasonably practical.

On Cosumnes River and tributaries there is a total drainage area of 160.51 sq. miles, of which 14.43 sq. miles are tributary to Sly Park reservoir, and the remainder, 146.98, to Buck's Bar reservoir. The run-off from these areas must be reinforced by that from South Fork of American River. This brings into service about 404 sq. miles of drainage area, about one half of which must be utilized by diversion canals, and one fifth of which is in private ownership, with several villages, the sewerage of which must by gravity flow reach the lower reservoir.

The conditions, therefore, granting that the complicated rights and titles shall be settled advantageously, are not comparable to the 635 sq. miles of uninhabitable area tributary to Hetch Hetchy and Lake Eleanor reservoirs of the Tuolumne.

The Bay Cities properties and claims have been thus fully presented and compared for the reason that the present Board of Supervisors have rejected all other sources and selected this

one at the price offered, namely, $10 500 000, as the one to be offered to the voters of the city.

The Board of Supervisors in 1902–4 called for offers of the Spring Valley Water Works and properties. But the requests were either technically avoided or ignored.

There have thus been four attempts by the city to gain possession of its water supply: (1) in 1871–2; (2) 1874–5; (3) 1876–7; and in 1900–6. What the result will be depends upon the intelligent and unselfish action of its citizens and officials. But judging from the supreme indifference with which the majority of the citizens of San Francisco look upon the situation, and the skill and cunning with which corporate control is managed, there appears little hope for any betterment either in the purity and abundance of the supply or the rate at which it is furnished.

There were gross and irremediable blunders made by the Spring Valley Water Company in sending its chief engineer on to Washington to oppose the applications of the city for reservoir rights of way, and in the importation of false representation of facts into the Modesto and Turlock irrigation districts. It is possible that the more thoughtful and far-seeing of its officers realize these blunders. Such methods have convinced many conservative minds, previously inclined to treat openly and generously with the company, that they have an unscrupulous monopoly to deal with, which is ready to adopt any means to thwart the ultimate good of San Francisco for its own selfish ends. The effect of this action may prolong monopoly ownership of this necessity, but it may eventually be the crowning act which will cause San Francisco voters to select some other source.

The Struggle for Purity.

In addition to the struggle for ownership, there is going on a more vital one for the purity of the supply. As the regions around our great cities inevitably become more densely occupied, the sources once pure become polluted. Whether this pollution comes from denuded mountains, cattle ranges and pastures, from farms and barnyards, from villages and towns, or from manufactories and mines, the results are to render the earlier selected sources unfit for domestic use. Not until the penalty is paid in human suffering and death is this pollution remedied, and even then the cost in dollars is frequently pitted against the cost in lives, at the expense of the latter. In notable instances on

this coast, such as Portland and Seattle, the lesson is thoroughly learned and the purest water, at any cost, is introduced, with a result which these cities would not exchange at any price.

The remedies lie along five general lines: (1) A change of source, as in the instances just cited; (2) storage of a partially polluted supply and exposure in the reservoir for as long a period as possible, as in Boston, New York, Baltimore, Richmond, etc.; (3) sand filtration, as in Berlin, Washington and as under way in Philadelphia, etc.; (4) sedimentation and treatment with flocculents or astringent salts of iron or alumina, and precipitating these with lime, etc.; (5) bactericidal processes involving the use of ozone.

If the first of these can be satisfactorily accomplished by the utilization of an uninhabited or sparsely settled area or a deep underground supply, it is far preferable, as a water supply which does not require a chemist's and a bacteriologist's certificate as to purity is best.

(2) Storage in reservoirs for at least two seasons is satisfactory where the drainage area is reasonably clean, but easily borders on the dangerous, as in Baltimore.

(3) Sand filtration, where properly applied, is highly satisfactory, but costly, and requires the most conscientious and skilled care.

(4) The same is true of treatment with flocculents.

(5) The use of ozone has been found highly efficient in France, Holland, Belgium and Germany, and a test plant in Philadelphia thoroughly purifies 1 000 000 gal. per day of the highly dangerous water of Schuylkill River. The prime element in this process is the cheap generation of ozone. The efficiency is unquestioned when compared even with sand filtration.

On all of the purifying methods the engineer is confronted by innumerable patents; even in the old sand filtration process there are recent patents for preliminary filtration, modes of removing and washing sand, etc., whilst in the use of flocculents and ozone the number of patents is legion.

In meeting the dangers and penalties of impure water, resort is had to a partial use of distilled and bottled spring waters. These are distributed in all cities to an extent which imposes a heavy expense. During recent repeated visits to Boston, New York, Philadelphia, Baltimore and Washington, the writer endeavored to get some idea of this expense. The figures ascertainable were far from complete, but indicated that not less than $8 000 000 is the annual expenditure in the cities

named, which, capitalized, represents a principal of $200 000 000. If to this be added the cost of boiling the water furnished by these municipalities, the capital would exceed the value of the combined municipal plants of these cities.

Even at this expense the consequences of an impure municipal water supply are but partly escaped.

There is just starting a struggle on new lines, namely, that against an excess of the mineral or soluble contents of the water.

It has been found that certain salts, notably of lime, alumina, silica and magnesia, when present in amounts from 20 to 35 gr. per gal. and when constantly used, result in obscure heart and kidney diseases. The former is peculiarly prevalent on this coast. These organs, under the constant strain of eliminating or of working under the disadvantage of an excess of mineral matter in the blood, yield in middle age to these fatal troubles. It has long been considered profitable to remove these salts from water used in boilers, but to remove them from the water consumed in the more delicate human system is not profitable in coin and is only paid for in life and health.

Many regard 40 gr. per gal. as a safe limit, but the writer is inclined to reduce this limit to one third or even one fourth this amount, if reasonably possible.

The great improvement in health in Portland since the introduction of water of the highest standard of purity warrants this rigid limit.

This struggle is, therefore, not ended when a city gains control. New York had the battle of its life to prevent the Ramapo Water Company from wresting control from its hands and placing an enormous tribute upon every home and every industry within its borders. San Francisco's struggle, we have seen, commenced in 1871 and appears no nearer an end at the dawn of 1907.

In all of these struggles it is manifest that the source of political corruption is not in official life, but in the body politic, in the ranks of those who pose as good citizens and, as directors and officers of great corporations, enjoying or desirous of securing monopolies, prey on the public through the non-official "political boss."

This creature is not the natural product of our political system, but the outgrowth and necessary adjunct of monopoly. When an official is false to his trust, there is almost always this go-between, this procurer, and his master the holder of or the seeker for a monopoly.

In New York it was the firm stand of one official that saved that metropolis its water supply. He fought alone until the public could come to his aid, and it took years of struggle to win.

In San Francisco it has been and is incivism and neglect of public duty which has lengthened out the fight over to a third of a century. However zealous groups of officials may have been at various stages of this struggle, the indifference of the public generally is the true cause of our repeated failures. This indifference is taken advantage of by those who have, or believe they have, rights for sale to the city.

We have a marked example in Oakland, where, after a judicial determination of the value at a figure probably double the actual investment, the "works" have been "capitalized" at nearly six times the judicially fixed value.

Whether a similar fate awaits San Francisco remains to be seen, although the existing works are already capitalized at a figure sixteen millions of dollars greater than the cost of the best of the Sierra sources.

In conclusion: Since these affairs are undertaken in our country only when a majority of the voters has knowingly or ignorantly expressed its decision, the details of these struggles should be known to every citizen of every municipality. These details are essential facts of which he must be cognizant in order to form a correct judgment as to the most important function which his municipality has to perform. When it is considered that "the health of a city depends more on its water than on all the rest of its eatables and drinkables put together," that the health of successive generations of mothers and children depends upon the purity of the water supply of the home, then, indeed, does the source of this water become to the civil engineer "the holy of holies." Then does this prime factor, *purity*, stand forth in strong light, and the minor factors — What does it cost? What per cent. do the stock or bonds yield? — shrink into insignificance. When these factors are considered in their true relation, municipal ownership of this necessity of existence and health is the only solution. The smaller questions of street railroads, telephone, gas and electric power can well be let alone until a city can say, *We own our water supply. It is pure and its sources unpollutable; it is abundant in every home within our limits.*

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, 31 Milk St., Boston, by May 15, 1907, for publication in a subsequent number of the JOURNAL.]

REPLACEMENT OF BRIDGES AND ALLIED STRUCTURES.

By Herman K. Higgins, Member Boston Society of Civil Engineers.

[Read before the Society, January 23, 1907.]

The writer was for several years in the employ of a railroad company. Part of his duties consisted in the examination of structures for the purpose of determining, first, when they should be replaced; second, what loads they should be allowed to carry in the meantime. Some of the conclusions he has arrived at may be pertinent and possibly useful.

Many of us (the writer included) are accustomed to consider bridges as classified, (*a*) by material, — stone, concrete, iron, wood, etc., — and (*b*) by use, — highway, railway, etc. In the olden time when the writer was forming his bridge habits (many of which he has found occasion to change) the classification by use was characteristic, — highway bridge practice being materially different from railway practice. Since the advent of interurban street railway and motor vehicles the distinction has largely disappeared, and in many respects the two classes are now practically one.

Classification by material is still to a great extent characteristic, although the lines of demarkation are becoming much less sharply defined. The reinforced arch, for example, is neither like a stone arch which it resembles in appearance, nor like a plate girder nor a continuous column, which it resembles (somewhat) in stress analysis.

The writer has in recent years thought of bridges as classified thus:

1. Stone, voussoir arch, including brick, and block concrete. 2. Concrete, monolithic, hinged or not, reinforced or not. 3. Iron or steel, with floors of any material. 4. Wooden, with only part of tension members of metal and with bolts, spikes, etc., of iron or steel.

These four classes call for somewhat different treatment in detail, the general considerations remaining the same for all.

The determination of the proper time for renewal of a structure ("structures" being a term to cover many things besides bridges) is a much more complex problem than is often supposed. It depends upon design, condition, present loads,

probable future loads, maximum *v.* ruling loads, and last, but not least, on many economic considerations.

In order to judge intelligently and get the full life of structures a comprehensive system of inspection with reports and permanent records is necessary. Many structures likely to be condemned under irregular inspection would be retained under a regular system of examination and recorded reports. It will readily be seen that in the nature of things this must be so. If the inspector knows that he will see the structure again in six months or a year, he can work much closer to the full useful life of his material. If he does not know when the structure is to be next examined, he will, properly, condemn everything that falls below a high standard even when he knows it is good for one or possibly three years but not longer. A proper system of records also allows him to devote an extra proportion of attention to older structures. There is a chance for much waste right here in the absence of system.

Stone bridges, also brick, were, not so very long since, thought to be permanent. The older arches are, under present train and highway loads, often in need of careful watching; fortunately they always give notice of overstraining, and intelligent supervision will often hold them in service long after the stresses approach the elastic limit, indicated by cracking and spalling. These structures were designed long ago for loads then absurdly heavy but now outgrown; and loads are still growing. It may be that an occasional excessive load may be tolerated, whereas the ruling load must always be within safe limits to provide for the appreciable though unmeasurable effect of fatigue of material. It frequently is the case that very inexpensive repairs, — concrete lining, buttresses and buttress arches of brick or concrete, iron tie rods, etc., — will suffice to make the structure perfectly safe and secure for many years more, especially when economic conditions make entire reconstruction inadvisable.

Block concrete (voussoir) arches are not often met with, but compare in all respects, except unit stresses, with stone arches.

Concrete arches, monolithic, reinforced or not, are of comparatively recent date and have not yet begun to approach their limit of life. They differ from stone in that internal conditions cannot so readily be judged by external signs. It is going to be a very ticklish proposition to know just when to condemn such bridges. What knowledge we have of them is based almost entirely on laboratory tests, and the few service

tests available indicate the need of much caution. The writer does not consider it safe to approach anywhere near as close to the elastic limit as good practice warrants with either of the other types of bridges. By the time these structures approach their limit of usefulness, many, if not most, of the records pertaining to their original construction will have been lost. It is so with many old bridges built so lately that the writer can readily recall their preliminaries, and will, no doubt, continue to be the case. Roads built by promoters rarely have complete records of structures. With the original records missing, it will be impossible to correctly compute stresses, and the inspector will have no easy problem to solve. An iron or wooden bridge can be measured, a stone arch can at least be approximated, but to measure the iron in a Monier or Melan bridge will require a divining rod that will make the witch hazel of olden days look very old fashioned. Even in case the records are available the inspector's path is by no means lined with roses. The effect of vibration with modern loads is not well known nor is the quality of the concrete used. In a couple of generations this problem may be historical only, but the writer believes that most of the concrete structures of this generation will have become historical also. We need permanent records and recorded and published experience. We shall continue to build concrete structures and we greatly appreciate the experimental data prepared for us by so many eminent members of this and other societies. We could do little without it; nevertheless, we do not know nearly as much about concrete as we do about iron or stone, and as bridge inspectors we shall feel suspicious of every crack and stain, however harmless, till we can find out what caused it.

Iron or steel structures nearly always present a comparatively easy problem. If original plans are missing, they can usually be obtained from the builder, whose enterprise in advertising (by name plate) often fills a serious blank in records. The condition of the iron is apparent on proper examination. It may help some one to mention some of the locations of incipient failure. In old structures the rivets and splices usually show earliest signs of distress. Plate girders and built up beams need special attention to web rivets near ends; the hammer will not find the trouble; white paint before the last rain is much better but often not attainable; there is often some sign of motion of flange angles on webs. If motion exists, the structure should be watched for increase of motion. If it does

not increase, there is usually no cause for alarm. When it does, measures should be taken to stop it.

Lateral and sway connections are often weak and work loose; often a few rivets a size larger and some reaming of holes will suffice as a remedy.

Roller bearings that do not roll are the rule for old bridges and are important only on long spans.

If badly rusted, plate girders should be examined for holes in webs near corners adjacent to flange angles.

In truss bridges one should look for " upholstered " struts, rust streaked plates near and below riveted joints, weak details of tension members and laterals, pins subject to severe bending moment; old pins were often small and members were often put on at variance from plans. Details near bearings on masonry are often subject to excessive corrosion.

Sometimes abutments and parapets move and " pinch " the structure. This applies to all bridges, — iron and wood.

Truss pins should always have cotters outside the nuts. Old bridges usually do not. Nuts may be keyed on with machine screws. One should look for missing nuts and pins working out, also for loose rivets at floor connections, also for evidence of wear of pin at foot of hip verticals.

When the structure is known to agree with the plans, the stresses may be computed. For old structures the writer believes the best method involves the old-fashioned " wheel loads." He prefers and uses the diagram of moments in the older editions (1890) of DuBois, "Strains in Framed Structures " checked by comparison with older computations. This diagram is sufficiently elastic to use when all or few members are in question; it is little work to make a diagram for each class of locomotives as it appears on the road; it gives as close approximations as are warranted by the indeterminancy of load distribution. The writer uses graphic analysis and " equivalent loads " on design of new structures, but believes that for old structures the analytical (so-called) determination is preferable.

Unit stresses must be kept below the elastic limit even for the most occasional loads and after liberal allowance for impact has been made. In determining allowable unit stresses, knowledge of the composition and molecular structure of the metal will often provide data of great value. It is often possible to get samples for analysis and micro-examination. This must, of course, be done intelligently to be of value, and sound judgment is needed to determine when the expense of such testing will

be warranted. A soft, fibrous, homogeneous material can safely be allowed to carry loads close to its probable elastic limit, whereas a crystalline, hard or streaky specimen should have a good margin. Sulphur and phosphorus in any considerable quantity subject a specimen to serious suspicion. Manganese, on the contrary, is an element of safety if not grossly in excess.

Rivets are the most unsatisfactory and indeterminate element in the structure. Only one who saw them driven can properly judge them. The hammer and touch test is useful but not certain. The writer has seen five-eighths rivets put into seven-eighths holes and headed to give perfect appearing heads, and they were tight. The hammer was defeated as a test. The inspector (the writer) was not known to the gang and happened to see the trick done. Most of the rivets in the truss in question were planned of the small size so the danger of non discovery was real. Many, if not most, old bridges were built without inspection. What wonder that we need to examine rivets with care. The writer has also seen (not on his own work) rivets drawn down to enter a badly matched hole. With full size heads both sides, this fault is undiscoverable. After all tests are applied it is, with old bridges, a matter of faith and careful examination for evidence of movement in the joint. It will surely move before it fails and proper inspection will detect danger before it becomes imminent. Rivets rarely fail in shear. They are safe in most cases up to unit stress seven-tenths of tensile elastic limit or even more, if shop work is first class. The bearing or crippling unit stress can run much higher, nearly to the ultimate strength of the iron. The writer knows of bridge girders in service up to within a few years, the rivets in which, figured by the usual methods, were carrying pressures 25 per cent. in excess of the probable ultimate compressive strength of the iron. The shop work was extra good, iron well fitted, and friction well developed. There never was the slightest sign of distress. In such cases the writer has always considered high bearing stress on rivets rather a suspicious than a positive indication. Such structures should be watched.

The floors of iron and steel bridges need as careful examination as the main girders. The old way (still current) of using two layers of plank on highway bridges is pernicious in many places. The lower plank decays, the upper wears or decays. On city bridges, which require a new layer of wearing plank every six months or oftener, the double plank is economical and safe, as the frequent renewals of wearing plank allow

effective inspection. On town and country bridges the upper layer decays rather than wears, and the writer has usually found the lower plank in decidedly unsatisfactory condition, entirely unfit to discharge its proper function, the carrying of the loads to the stringers. The writer considers all such floors subject to suspicion and has usually recommended their replacement with a single layer of plank usually thicker than the original bottom layer. Four-inch plank is heavy enough in most cases and leaves the floor determinate.

Wooden bridges often surprise us by their capacity for carrying overloads, not safely, but nevertheless successfully in many instances.

The construction of electric railways often proves the limiting feature of wooden highway bridges, and it may well happen that the distribution of material and the moving of machinery imposes a greater strain on the bridge than the operation of the cars. These loads being rare and the cars frequent, it may still prove to be the cars that make necessary the renewal of the bridge.

City bridges are more often of iron than country bridges and are subject to corrosion in concealed places; country bridges when of iron often lack paint and corrode in exposed places.

Wooden stringer bridges usually show most decay in the middle of tops of stringers. The writer considers such decay usually not a cause for renewal until it extends far enough to cause spreading or local crushing of the stringer. This principle does not hold for concentrated loads or bearings on wall plates. These must be sound.

Timber protected from weather is subject to a form of deterioration quite distinct from decay. Builders would say, it has lost its " life," it becomes soft and punky, the grain does not separate properly. Such timber should be replaced.

Timbers of different species often destroy each other. A Howe truss with pine or spruce posts (struts) and oak angle blocks has been known to retain a mere shell of sound timber in the braces, the interior near the ends being like cheese. Only the auger intelligently used will detect this form of decay. Truss chords near oak clamps and keys will bear close examination. A chord failure usually means business for the wrecking train. Counters sometimes break short off; they need attention, especially when old.

There are often economic reasons, and political as well, which finally prove most important factors in the determination

of time of replacement. With highways the political predominates, with railways usually the economic.

It is commonly but incorrectly believed that railways keep their structures up to the requirements of their heaviest rolling stock. As most of our railways, in the East, at least, were built some time ago, it will readily be seen that there must be many antiquated structures to limit the allowed traffic. The better the structure originally was, the more likely it is to be or become a limiting feature of the road.

Most railroads, if not all, — the writer recalls no exceptions, — publish a schedule for the use of freight shipping agents, showing allowed loads for each line between junctions or important stations. Any load offered in excess of these allowed loads is either reloaded to give lower wheel loads, or sent by a slightly differing route. This means that for each line between such points there may be one or more structures the strength of which limits the safe load. In case the line has been in existence for some years it usually is the case that there are several such structures, or in case the line was built by promoters, as is often the case, all the structures are equally light. It may well be that they are as good as new, only weak. If the traffic on such line is not too heavy or if the line is not part of a main trunk line, it will manifestly not pay to rebuild one or all the bridges, but the loads will be limited. Of course there is also a similar schedule for operating and motive power officials, showing limits for locomotives.

If, on the other hand, a single bridge limits the traffic, it becomes purely an economic problem to work out the advantage to be gained by its replacement.

In case the completion of a new connecting line opens up a new trunk line, or even an alternative line to be used as a trunk line in case of wreck or emergency, it may be the wisest course to replace the many structures. It may happen not to be a bridge that limits the line, but a turntable at a critical point, an ash pit, a roundhouse, a station with covered train shed; any of these or other conditions may limit the weight or size of locomotives and render unwise, that is, uneconomical, the replacement of other structures, weak but sound and in good condition and sufficient for the traffic as limited.

On branch lines it is nearly always an economic problem and may be political as well.

Perhaps some much desired industry needs facilities for handling heavy loads.

The near expiration of a lease may render it very unprofitable to rebuild a structure, even at the alternative of excessive repair charges.

On main lines it is sometimes needful to run heavy trains for advertising purposes even at an economic loss. Many structures are rebuilt for this reason long before weaker structures on branch lines are even strengthened.

It will thus be seen that economic or business or even political considerations may take precedence of strictly engineering or constructive problems, in determining time of replacement of structures.

After replacement is determined upon there is still a chance for economic errors of design which will make trouble later. A line good for only say 120 000 lb., on account of structures in first-class condition but of weak design, would not be entitled to 200 000 lb. structures, unless the latter are to outlive the former, and unless the future cost of strengthening will considerably exceed the present cost, enough to pay the interest at least. A structure near the end of a weak division adjacent to one stronger may well be made equal to the stronger division. In any case the economic problem should be worked out.

Since beginning the above, a paper has been presented at the 1906 September meeting of the American Society of Civil Engineers and abstracted in *Engineering News*, August 23, in which the author, Mr. W. J. Watson, Bridge Engineer of the Osborn Engineering Company, covers similar ground to the above. An editorial in *Engineering News* in September also attacks the same problem. It will be seen that the present writer has ideas somewhat at variance with those expressed by Mr. Watson and the editor. This is, no doubt, partly due to a different set of conditions, and partly to the inevitable difference of opinion between different individuals. Where such differences exist the writer sees no occasion to change his former conclusions.

DISCUSSION.

Mr. J. Parker Snow (by letter). — The subject of the paper is one of vital interest and importance to all railroad men. Much has been written upon it, and it is one of the subjects now being particularly studied by a committee of the American Railway Engineering and Maintenance of Way Association.

In addition to the paper by Mr. Watson, cited by the author, the following may be named: A paper by A. J. Himes, in *Bulletin 80*, October, 1906, American Railway Engineering and Main-

tenance of Way Association, which contains references to several papers and articles besides that of Mr. Watson; a paper by Wm. Marriott on strengthening early iron bridges, and the Austrian Railway Ministerial Order of August 28, 1904, concerning new and old bridges, both of which are in *Bulletin 4*, April, 1906, vol. xx, of the International Railway Congress; and a paper by J. E. Greiner on the "Life of Iron Railroad Bridges" in Transactions American Society Civil Engineers, vol. xxxiv, page 294. A paper by Mr. C. D. Purdon in the Journal of Engineering Societies, vol. xxxiii, page 325, gives a method of classifying locomotives as to their effect on bridges, together with a sample schedule of bridges, which shows at a glance the approximate maximum strain on every bridge under any locomotive that has been classified.

I agree entirely with the author that much depends on field examination in determining whether a bridge should be retained, strengthened or rebuilt for existing traffic. A table for each structure, showing the maximum unit strain in its various parts, should be in hand when such examinations are made. Rivets especially are to be judged almost wholly by their action in service. Much has been written about allowable shear and bearing strains, dependence upon friction, etc.; and, of course, high units are proper signals for examination, but if they keep tight they can be trusted. As the author says, they rarely fail by shear; they will show their weakness by becoming loose long before they will fail.

Timber bridges show distress much more plainly than those of metal, but the latter can be so examined as to show signs of weakness long before failure need be feared under existing traffic.

The principal difficulty that confronts an engineer responsible for bridges arises from the desire to increase the loading on old bridges. In this case he must judge what will be probably reasonably safe from the computed unit strains. He has much to guide him by a study of the structures that show weakness under existing loads, but no fixed rule can be assumed, because no two structures behave exactly alike. My experience has brought me to the conclusions expressed in this and the following paragraph. They are the basis of my practice in handling old bridges, but I should not wish others to follow these rules literally, because in every case judgment based on the action of the structure in question under load must temper the said rules. Pin trusses built 30 years ago will not bear the unit strains that riveted trusses of the same age will; and of the

latter, a pony truss will bear higher strains than a deep through truss. This latter is contrary to the teaching of many engineers, but experience proves it to my mind. Plate girders merit the confidence that all repose in them; but riveted pony trusses behave, with me, just as satisfactorily. The only way that I have known plate girders to fail has been by the top flange getting loose on the web in deck structures. This is due to wheel loads rather than to flange strain; they become loose near the center of span as generally as at the ends. The allowed unit strain may well be 25 per cent. higher in the one type of bridge named above than in the other. Within limits, also, quite short spans, say below 20 ft., may be allowed to carry higher strains than longer ones. This with loads figured as static. I realize that this is another case of heresy, but I am sure it is true. The reason may be that the frame of the engine assists the bridge, or that the running rail helps it out, but the fact remains that at 5 ft. any old stringer will do, even if it figures above the breaking strain.

Our author does not fix upon an allowable unit strain. It is delicate ground, but without some basis for discussion no definite result can be reached. The unit strain and the impact allowance, as it is generally called, are balanced factors, and no intelligent consideration of the matter can be reached without treating them simultaneously. Again, in making impact allowance, the question of speed must be taken into account. Ordinary railroad traffic at speeds below 20 miles per hr. may be considered as static. At 60 miles the allowable unit should be decreased 25 per cent. or the load increased 33 per cent., if a constant unit is used, on ordinary types of 100 ft. span and less. With these features in mind, the ordinary units used in designing may be doubled before a bridge need be condemned for high strains. This is a broad rule; its application needs to be varied to fit each individual case.

There is a wide difference of opinion among laymen, and quite a little among engineers, as to whether a bridge is suitable for given loads. This difference covers all the ground between not exceeding the load for which the bridge was designed and the idea that this load can be multiplied by the ratio of the ultimate strength to the unit strain used in the design (the so-called factor of safety) before the bridge will fail. Both these views are manifestly extreme. The first would seem to claim that if bridges will carry safely more load than that for which they were designed they are thereby proved to be un-

necessarily heavy. We sometimes hear it said that they are purposely made over-strong to provide for future increase of loads, but if we ask just how much overload is provided for the answer is indefinite. If we expect a certain overload we ought to take that load as our weight to start the design with. The fact is we do not design our structures to just carry the prescribed load with safety and not break down, but to carry it satisfactorily; and every increase of the prescribed load will decrease the satisfactory working of the bridge. The vibration and deflection will increase under increased loads and more frequent repairs will be called for until the load is such that the strains in first class riveted work are about twice what were used in the design, when the action of the bridge will generally become so unsatisfactory that its renewal will be welcomed by all. Multiplying the original load by the so-called factor of safety cannot be done on account of unequal distribution of strains, imperfect material and rough workmanship.

Of course deterioration is a live factor in condemning bridges. The author covers that feature fully. Modern structural steel corrodes with alaiming rapidity. Why it should corrode so much faster than wrought iron is being studied by a Committee of the American Society for Testing Materials. The question of molecular change (crystallization) is not talked about so much now as formerly. If badly overstrained, say about three times the allowable unit, iron will get brittle; but most of the brittle material found accidentally in service was just as brittle when put in as when found.

The celebrated paper by Mr. Watson, referred to by the author, advocates the Pritchard formula for impact when investigating old structures. A comparison of this formula with others is given in the annual proceedings of the American Railway Engineering and Maintenance of Way Association, vol. vi (1905), page 257. That comparison shows that for ordinary tie-floor single-track railroad bridges there is but little difference in the final results between the Pritchard, the Schneider and the Cain formulas. For double-track trusses and floor beams the Schneider formula gives more reasonable results than the others, while for ballast floor bridges the opposite may be true.

These formulas were designed for use in proportioning new bridges and they provide very liberally for the impact of moving trains as well as for secondary strains due to non-symmetrical connections. If applied in analyzing old bridges a unit strain of at least 25 000 should be used and then many short bridges

will be ruled out that are entirely adequate for the desired service. It must be remembered that these formulas provide for speeds of 60 miles per hr. or over, and if slower speeds obtain, the impact addition may be less. I prefer computations on a static basis and unit strains varying from 15 000 to 20 000 according to judgment.

Timber stringers, if fairly sound, will not fail at 2 400 fiber strain. In tension or compression, however, timber will not generally safely carry this strain. In this case it becomes a matter of side support and end connections which in timber trusses are generally very faulty.

Concerning the deterioration of timber, the author's remarks accord with my experience. A feature not touched upon by him is the fact of greater durability of timber in cold climates than in warm. Altitude is equivalent to higher latitude in this respect; and the difference in the life of exposed timber is very marked between the latitudes of Boston and Montpelier, and between the altitude of Boston and Ashburnham, Mass. The difference in the life of Southern long leaf pine is fully three years at the points named.

Mr. Joseph R. Worcester (by letter). — Mr. Higgins has chosen a subject of great importance, and his treatment of the question is, in the main, entirely satisfactory. There are one or two points, however, upon which he is not quite so specific in his recommendations as might be desired.

He states that unit strains in metallic structures should never be allowed to reach the elastic limit of the metal. In this there can be no doubt that all engineers will agree, but are we to assume that, if the strains do not reach the elastic limit, he would pass the structure as safe? In other words, would he allow a tensile strain in a main member of steel of 30 000 lb. per sq. in.?

Mr. J. E. Greiner, assistant chief engineer of the Baltimore & Ohio R. R., in a discussion of the subject for the Committee on Iron and Steel Structures of the American Railway Engineering and Maintenance of Way Association, has recently presented a convincing argument against allowing any higher strains in old structures, in which there exist uncertainties as to the nature of material as well as perhaps imperfectly designed details, than would be allowed in new structures, properly designed and built of carefully inspected material. As against this, of course, we may say that in designing new structures we advisedly use lower strains than we know to be safe, for the very

purpose of providing for an unknown future increase of live load. It is, however, an illogical method of making this provision. When modern specifications are tending more and more toward the method of reducing all possible strains, including impact, to an equivalent static strain, and using for the unit strain a flat unit supposed to be correct for a static load, we should logically, if we want to provide for an increase in future loading, make the desired provision by an increase in the assumed live load.

The general practice at the present time, both for railway and highway bridges, as well as for other structures, is to use a unit strain of about one half the elastic limit of the material. This factor is considered correct in places where the load assumed is an absolute maximum, as, for instance, where it consists of a definitely determined dead load only. There is reason enough for allowing this factor on account of possible irregularity in the metal and internal stresses due to imperfection of details. Can it be said that these elements are less likely to be present in old structures than in new? Manifestly not.

The only excuse for allowing this factor to be reduced in an old structure would be that by careful watching it might be safe to rely upon distress becoming apparent before an accident could result. This would seem to be a doubtful dependence unless an almost daily careful inspection were made, which would be well-nigh impossible.

It is to be hoped that the author will give us more specifically his views upon this point.

The author tells us that the hammer is not a sure guide in the detection of overstrained rivets. The writer agrees so far as to admit that no examination of a structure without calculation of strains is as safe as careful analysis. At the same time the writer has always held the opinion that a rivet which was really tight under the hammer was doing its work, and that it would give evidence of weakness, by becoming loose, before it would fail. It is undoubtedly true that many rivets, if not all, do their work solely by clamping the parts together so strongly that motion is prevented by friction, even though the shank does not bear on either side. This condition is perfectly normal, and so long as the friction is sufficient, is ideal. The time will come, in the writer's opinion, when rivets will be figured by friction, which bears a constant relation to the shearing strength, rather than by bearing and shear, which never are called into play until the joint slips to some extent. Even

when the joint has slipped, and the bearing and shear come into action, if the rivet remains tight, it cannot have been seriously overstrained. If the author has seen cases where rivets ringing tight have failed in service, it would be instructive if he would describe the circumstances.

The author's fears with regard to the future of reinforced concrete bridges do not appear to be well-grounded if we may judge by analogy with reinforced concrete beams and slabs. In one respect, at least, there is an element of safety in all concrete structures not existing in stone and brick, that is, the growth in strength that occurs in this material with age. It seems probable that where the determining strain is pure compression, this increase in strength ought to go far towards taking care of the increase in live loads for a very considerable period. On the other hand, the addition of a tensile strength at the critical points of an arch, even though the exact amount or nature of the reinforcement is uncertain, should contribute a certain ductility above the elastic limit not possessed by *voussoir* masonry. It is well known that beams or slabs of reinforced concrete will often deflect to one thirtieth or one twentieth of their span before failure, while cracks may open almost enough to allow the reinforcement to be measured. These circumstances certainly ought not to be considered as adding anything to the hazard.

Prof. George F. Swain. — I have listened with much interest to the paper by Mr. Higgins and to the discussions which have been read by the secretary. They bring out many interesting points. My own feeling is that the inspection and replacing of old structures demand a very high degree of judgment and experience on the part of the engineer. His attitude of mind must be quite different from that of the designing engineer, who merely has a set of specifications to go by and makes his structure strong enough so that it will be sure to carry its load safely. The engineer who has to consider an old structure must be able to judge of the faults of the original design, to estimate their effect, to recognize signs of incipient failure and to judge of their seriousness; and it is frequently a matter of great importance to his company whether he is willing to allow a structure to remain or whether he condemns it. It is very easy to condemn a structure, but it sometimes difficult to recognize that it is safe in spite of defects or weakness. The opinion of the writer was asked not long ago with reference to the renewal of a large and important bridge. It was weak in some parts and much lighter than would be built at the present time, but the

writer satisfied himself that it was safe and reported to the company that it need not be renewed at the time when his opinion was asked. The money which would otherwise have been required for its reconstruction was used in a way where it was greatly needed and the bridge continued to carry its load until a later date, when it was found more convenient to renew it.

In judging of old structures, the engineer will be assisted by remembering two facts: First, that the engineer is aided by nature; and second, that many things help support a structure which are not allowed for in the usual computations.

With reference to the first of these, a structure will stand up if it is a physical possibility for it to do so; that is to say, if a condition of stress is possible which is consistent with the physical conditions and the conditions of equilibrium. The yielding of one piece will throw the stress elsewhere. Even the failure of a piece usually considered necessary does not always mean the destruction of the structure.

With reference to the second point: In short wooden stringer spans, for instance, while we consider the load to be carried by the stringers under the rails in reality there are, in addition, as a rule, guard timbers, two track rails, frequently two guard rails and frequently side stringers. Many short spans would stand with perfect safety if the stringers under the rails were entirely removed. Then, again, friction is an element which frequently helps. In wooden trusses it is often the factor which really causes the truss to stand up. In riveted structures the friction on the rivets, usually neglected, may be sufficient to carry the entire stress on the rivets. The writer does not, however, agree with Mr. Worcester in believing that it would be proper to allow for this friction, since it is an essentially uncertain quantity, while the strength of the rivet is a positive quantity. Again, we allow for the nominal diameter of the rivet while in reality the rivet is about $\frac{1}{8}$ in. larger. With a $\frac{7}{8}$-in. rivet, this alone gives an increase in strength of about 15 per cent. Another practice of many engineers in not allowing for the action of the web of a plate girder in carrying the moment is an incorrect assumption on the safe side, like many others frequently made. In all of these ways many structures are really much stronger than they are computed to be.

It has been the writer's practice to allow the stress in the main members of a structure, making in some cases some allowance for impact, to reach about three fourths of the elastic limit before considering the structure to have reached the danger line.

No definite rule, however, can be laid down, as varying circumstances must be taken into account.

The writer believes, in the case of steel structures, that the principal cause of renewals is defects in design and not overstraining of the main parts. The loads to be carried by railroad bridges have increased very much in the past 30 years and yet there are many well-designed railroad bridges built 30 years ago which are still in existence and carrying these increased loads with perfect safety. On the other hand, some structures 15 years old or less have had to be renewed on account of defects in design, although the increase in weight of rolling stock has been comparatively small. A great deal of money has been wasted for our railroad corporations by improper design.

Coming to specific defects, the writer would like to say a few words in favor of the reliability of hard pine as a structural material. He has always found that after some years' service hard pine looks much worse than it is. The sap decays, but the interior of the stick not more than ½ in. to 1 in. from the outside is generally perfectly sound. White pine, on the contrary, he has not infrequently found unreliable and subject to dry rot. Many, if not most, of the wooden trusses built 30 to 50 years ago, in this part of the country at least, were built of white pine. The writer remembers one occasion in which he discovered by the use of the auger that three out of four sticks in a lower chord of such a truss were mere shells. In the examination of wooden trusses he has found that while the auger is, of course, the most useful instrument, the sound under a hammer, and even the color of the wood, are sometimes valuable and reliable indications.

The writer knows of no reliable means of ascertaining whether the vertical members of a Howe truss are equally stressed, unless they happen to be of equal size and of the same free length, in which case the sound under the hammer will be a good indication. If the sizes of the bars in one member are different, or if they have not the same free length, the sound will, of course, be no indication at all. The writer believes that such bars are often very unequally stressed.

With reference to steel structures, the writer would refer to a few defects in design. One of these about which he has said a good deal in the past is found in riveted structures and consists in not bringing together the members at one joint so that the center of gravity lines intersect at a point, or as nearly so as practicable. The secondary stresses due to a violation of this rule are sometimes exceedingly large. Eccentric connections,

in which the center of gravity of the rivets which take the stress out of a piece does not lie in the center of gravity line of the piece, also cause large secondary stresses. Sometimes these may be computed in a simple way and with a fair degree of accuracy, and it is not uncommon to find designs in which the actual stress in some of the connections is three to five times that which is supposed to exist. Such cases have not been infrequent in the experience of the writer.

Another defect which the writer has met with is in proportioning the web of the plate girders too thin, due to an apparent failure to realize that the web acts as a column. In some plate girders a slight motion of the web may be discerned as the train passes over. The writer knows of many cases in which it has proved desirable to add stiffeners. A thin web, of course, is also objectionable in reducing the bearing value of the flange rivets, a matter which has been alluded to by Mr. Snow.

Another matter which the writer has frequently had occasion to observe has reference to the use of stiffeners under bracket angles in floor beams. The stringers which rest on these brackets deflect under the load, and the tendency is to concentrate the load which goes into the floor beams on the outer edge of the bracket angle. Unless properly stiffened or unless properly designed to resist this bending, such brackets are liable to fracture. This sometimes takes place at the inside of the horizontal leg and sometimes at the upper portion of the vertical leg. It is singular that so many brackets should have been used without any attention being paid to their design, and as a result the writer has found a number of instances in which such brackets have been broken. Professor McKibben will give the society some further details with reference to this.

I will only add that in the specifications of the railroad commissioners provision is made that such brackets shall be stiffened by angles beneath. If not so strengthened, a minimum thickness is prescribed, but stiffening is insisted upon wherever practicable.

Many other matters might be alluded to if time permitted, but I have already occupied too much of the time of the society.

Mr. Frank P. McKibben. — Mr. Higgins' interesting paper has touched upon many points which I hope will be fully discussed here to-night. The question of the distribution of loads upon highway bridges by the planking which forms the floors of such structures is one which is important not only in the study of existing bridges, but also in the design of new ones.

In the *design* of track stringers of highway bridges carrying electric cars, the stringers directly under the rails should be computed to carry the entire loads from the rails without relying upon the planking to distribute the loads to adjoining stringers. In the study of existing bridges of this kind it is frequently necessary, however, to assume that the planking distributes the track loads over a considerable width of the roadway and hence over several lines of stringers. If the planking is in good condition this assumption is allowable, but it is difficult or impossible to determine exactly how the loads are proportioned among the various stringers. A very common form of track construction is to have the rails resting directly upon a lower layer of planking, which, in turn, rests upon wooden stringers spaced 2½ ft. on centers with one stringer directly under each of the rails. In this case the amount of load upon each of the stringers is far from equal. Given an electric car axle-load in the *center* of an ordinary 13-ft. panel, with 4-in. by 14-in. stringers spaced as just mentioned, the rail resting on a layer of continuous 4-in. planking, it can be shown that approximately 30 per cent. of the axle load is carried by each of the stringers under the rails, 26 per cent. by the stringer under the center of the track and 7 per cent. by each of the two stringers just outside of the rail stringers. These percentages change somewhat with changes in the size of stringers, thickness of planking, etc., but are of sufficient accuracy to show that the assumption of *equal* distribution is incorrect. As the weights of electric cars increase this becomes a matter of considerable importance.

An examination of existing highway bridges carrying electric railway cars reveals one form of construction which is so prevalent and so poor that it should be emphasized in order that existing bridges having this defect may be strengthened and that the evil may be avoided in future construction. The practice to which reference is made is that of supporting wooden stringers upon small steel shelf angles riveted to the webs of floor beams, the shelf angles not being braced by stiffeners fitted under the outstanding legs. It is not at all uncommon to find electric railway tracks on highway bridges carried upon stringers which rest upon shelf angles as small as 3 in. by 3 in. by ⅜ in. Such angles are almost invariably overstressed, and the writer has in his possession *broken* shelf angles from three different bridges.

Let us assume the following case and investigate the shelf

angle. Panel length 13 ft., one stringer directly under each rail. each stringer supported at each end by one 3 in. by 3 in. by $\frac{3}{8}$ in. by 15-in. shelf angle riveted to the floor beam web, two wheel loads of 6 000 lb. each on a wheel base of $6\frac{1}{2}$ ft. These data give a maximum live end shear of 9 000 lb. on each stringer; say dead shear is 2 000 lb., total 11 000 lb. per stringer. The shelf angle must carry this and is subjected to a bending which is a maximum on horizontal sections just above the heads of the rivets which connect the shelf angle to the floor beam web. As the loads deflect the stringer the end shear of 11 000 lb. is at first thrown well out towards the outer edge of the horizontal leg of the shelf angle, but as this leg deflects under this load the resultant of the pressure acts nearer the vertical leg of the shelf angle. If the 11 000 lb. is assumed to be uniformly distributed over the outstanding leg, the maximum bending moment in the shelf angle is $11\,000 \times 1\frac{5}{16} = 14\,400$ in.-lb., and the maximum fiber stress in the angle is (neglecting a slight additional compression) $\dfrac{14\,400 \times 6}{15 \times \frac{3}{8} \times \frac{3}{8}} = 41\,000$ lb. per sq. in.

Of course as this angle receives this stress it bends downward and the stress is reduced, but that it is highly overstressed is obvious.

In many cases the shelf angle is made continuous along the floor beam instead of being used in short pieces under the stringers. This continuous angle is somewhat better than the series of short pieces, but unless made very thick is poor construction.

Stringers are frequently set directly on the top flange angles of floor beams without any stiffeners under them. This is also a poor form, since the outstanding leg of the top flange angle is subjected to a bending moment very similar to that already discussed. These top flange angles and the shelf angles should be provided with stiffeners properly fitted to the outstanding legs.

Mr. L. S. Cowles. — The author's idea of judging the fitness of an old bridge from a common-sense point of view rather than a too theoretical one seems to be the sanest method to pursue. However, the mere keeping of unit stresses below the elastic limit would hardly warrant a feeling of contentment for the inspecting engineer unless the stress were well below, or say under three quarters, of the elastic limit.

With regard to the indeterminate element of rivets in a structure, I feel that if a rivet is tight under the hammer test, it must be doing some of its intended work, even though it

does not fill the hole, or may otherwise lack the requirements of a so-called first-class rivet.

The most frequent overloading of city bridges seems to come from the ever-increasing weight of the electric car, whether urban or interurban. The main girders and trusses are no doubt less likely to be overstrained than the floor system, and especially the connections of stringers to floor beams. In old city bridges the practice of supporting wooden stringers carrying car tracks on single unsupported shelf angles is to be deplored, and all such defects should be remedied by means of vertical stiffeners under the outstanding leg of angle, or where there is not sufficient space the angle may be supported by vertical bolts and a yoke over the top chord of floor beam.

The question as to what constitutes a "liberal allowance" for impact for electric-car loading is a much mooted one. Mr. C. C. Schneider, in his very excellent paper on "Bridges for Electric Railways," *Street Railway Journal*, issue of September 22, 1906, introduces his impact formula for railroad bridges in a modified form, so that the addition for impact due to electric car loads is practically one half that due to locomotive loads. This seems perfectly safe, as the speed maintained on most electric railways is much lower than on trunk lines, and the rotating effects of the motors, is no doubt, less disastrous than the reciprocating motion of the steam locomotive parts. Certain defects common in the track system of many electric roads might tend to equal the pounding effect of poorly balanced locomotive driving wheels, but over such a roadbed high speeds could not with safety be maintained.

Referring to the ever-increasing electric car loads, it may be of interest to know that the heaviest surface car now being equipped on the Boston Elevated Railway system will weigh, when loaded, about 41 tons, and in case the motors are mounted on one truck only, the load on the motor truck will be about 25 tons, or practically the same as for an elevated car on the same system. It is thus seen that for short spans, such as stringers, this is equivalent to a 50-ton car, and in the light of present facts it would seem advisable to adopt as a standard a 50-ton electric car about 45 ft. long in designing new work where car tracks are to be supported.

Mr. Frederic H. Fay. — The speaker indorses, in the main, the author's views in regard to reinforced concrete arches and believes that his criticisms are applicable to reinforced concrete structures in general. While the strength of an existing

structure of wood or iron may be determined within reasonable limits from no other data than those obtained from a field examination, in the case of the structure of reinforced concrete, with the original records missing, it will be extremely difficult, if not impossible, to determine its strength by inspection. The increase in live loads should be taken into account when one is considering the question of building a bridge of steel or of reinforced concrete; and it should be remembered that while, in many cases, a steel structure can be built which will admit of future strengthening at slight expense, thereby prolonging its life, it is by no means a simple matter to strengthen a reinforced concrete structure. Because of this difficulty in strengthening, the uncertainties of workmanship and the practical impossibility of inspection in service without the original data, not to mention our present lack of knowledge of the behavior of reinforced concrete structures during a long term of years, the speaker believes that good designing calls for a considerably higher factor of safety in reinforced concrete structures than is used to-day in structures built of steel.

At the present time there is a remarkably rapid increase in live loads on highway bridges carrying street cars. In Boston, for example, a number of city bridges originally designed to carry a uniform live load of 100 lb. per sq. ft., or a single 20-ton wagon, are now being strengthened by the Boston Elevated Railway Company to take trolley cars weighing 50 tons.

Professor McKibben has shown some interesting examples of unstiffened shelf angles broken in service by excessive live loads. It will be noted that Professor McKibben's angles are short, and that in each instance they broke in the vertical leg near the root of the angle. The speaker has in mind some long, unstiffened, shelf angles which formerly carried the street railway track stringers on a bridge in Boston, and which broke in the horizontal (outstanding) leg. One of these broken angles is now in the city engineer's office. It is of wrought iron, 3 ft. long, with 3-in. vertical leg and $3\frac{1}{2}$-in. outstanding leg, and an original thickness of $\frac{3}{8}$ inch. The thickness had been reduced somewhat by rusting from locomotive gases. The break in the outstanding leg occurred near the root of the angle, this leg being sheared entirely off for a length of about 18 in., while cracks on the upper surface extended some distance beyond the ends of the break. It is believed that this break shows that in an unstiffened shelf angle the load from a stringer is not distributed over a considerable length of angle, — a point

which should be remembered in designing continuous shelf angles.

The speaker takes exception to the author's statements as to the advantages of a single layer of plank over two layers in the floors of highway bridges. Where one layer of floor planking is used it will usually be allowed to continue in service until it is worn nearly through or it actually breaks under some heavy load; in short, until it becomes dangerous. With two layers of plank, the lower layer should be designed for strength and the upper for wear; and even if the upper layer be worn entirely through, the strength of the lower planking remains to carry the load to the stringers. The author admits that on city bridges "the double plank is economical and safe, as the frequent renewals of wearing plank allow effective inspection." The speaker does *not* agree with the author's statement that on town and country bridges the lower layer of plank will rot out before the upper layer has become so unfit for service as to require renewal. The speaker is of the opinion that in all highway bridges with plank floor-surfacing, whether the bridges be for city or for country use, it is the better practice to use two layers of planking.

In the case of plank floor bridges over railroads, it is often desirable to provide floor planking which will require complete renewal at frequent intervals, for usually it is only when the planking is so renewed that the metal work beneath the floor is repainted. In such bridges it has been, for years, the practice of the city of Boston to use untreated spruce for the lower layer of planking as well as for the upper layer, in order that the lower planking would be renewed and the metal structure repainted with reasonable frequency.

[NOTE. — Further discussion of this paper is invited, to be received by Fred. Brooks, 31 Milk St., Boston, by May 15, 1907, for publication in a subsequent number of the JOURNAL.]

SOME ENGINEERING LESSONS OF THE SAN FRANCISCO DISASTER.

By J. L. Van Ornum, Member of the Engineers' Club of St. Louis.

[Read before the Club November 21, 1906.]

The modern city is the creation of commercial needs, and its location is fixed by commercial conditions. The duty of the structural engineer is to so plan all parts of the structure that it shall resist (1) with certainty all definite calls upon it; (2) with no serious injury all probable calls upon it; (3) and without destruction all those occasional visitations that human power can resist. Grouped under the first heading are the live-load, dead-load and the ordinary wind-load requirements, etc.; under the second heading would be grouped such occasional attacks as those of fire, gales and moderate earthquakes in earthquake regions; under the third head occur such disasters as hurricanes and tornadoes, general conflagrations and severe earthquakes, such as at times appall humanity in disasters that are made possible by reason of inadequate design or construction (or both), permitted in order to save a small percentage of expense, but thereby hazarding the integrity of all, with the gambler's chance of some gain or great loss.

Successful resistance to earthquakes, even when severe, is possible; but as this concerns most cities only remotely, it will be passed over with the statement that unified foundations structurally carried to solid material, with a thorough sway-bracing of the frame, will preserve the integrity of a steel building in any probable earthquake; even in masonry walls, bands of metal reduce to small proportions the damage to them from seismic disturbances. It is mainly with the fire lessons that we are concerned, because they are of universal interest and application. It is true that, often when discussing these lessons, we hear the remark that the Baltimore and other fires teach the same facts; but if we analyze more deeply, we must conclude that the San Francisco lessons are unique in giving us generally the effects of fire only, while nearly all others have left the added destructive action of water and steam upon the highly heated fire-resisting materials.

The main study, then, will be that of different engineering materials with regard to their earthquake-resisting and fire-

resisting properties. In view of the general conditions found to exist in San Francisco, as developed by his careful inspection of the city, the writer would impress with all the earnestness at his command the absolute necessity that good construction must follow a good design, or the result is a failure. Faulty design may be partly or wholly redeemed by excellent construction, but a thoroughly good design may easily be utterly ruined by defective construction. These facts are not at all new, but they are so evidently often obscured or ignored that it would be well if they might be impressed with all the vividness of a new thing. The engineer should always see to it that his design is constructed of adequately good materials and executed with the necessary skill and character of workmanship.

Passing the discussion of foundations (not because they are less important than any, but because the superstructure is most exposed to the destructive agencies under discussion), it may be said that wood resists earthquake vibrations well if the frame and roof are properly tied and braced; the almost universal practice is to ignore such bracing, and then the result is a collapse. In fire, wood, of course, "adds fuel to the flames." Masonry walls of all kinds resist the earthquake usually without destruction if well built, generally with considerable damage; the effectiveness of resistance is enormously increased with but little extra expense by improving the weak part of the wall — the mortar — by putting into the mortar a large proportion of Portland cement *; and a further effectiveness of resistance may be secured by metal ties and bands. Against fire, even without the rupturing and exploding action of water from the fire streams striking the highly heated materials, stone of practically all varieties spalled and disintegrated badly and in varying degrees, enough to require its replacing for the sake of appearance even when it was not structurally incapacitated.

In buildings in which steel enters as an essential structural element, more attention must be given to lateral bracing and to connections to make the structure safely resistant to earthquake vibrations. A more definite lateral stability must be furnished, with less reliance upon the indefinite internal rigidity of the finished structure.

In fire, the particularly vulnerable point of buildings of the first class remains the inadequate protection usually made

* The Appraisers' building, which survived without a crack, was built with brick laid in cement mortar, and is said to have had a monolithic concrete foundation 6 ft. thick capping the foundation piles.

against the introduction of fire from the outside, through windows, doors and inadequately designed roofs which quickly burned away. The protecting effect of metal shutters and metal covering of window trim was great, increasingly so as its character was better, and often so decisively effective as to permit the saving of the building at critical times, as the Kohl building. Even without such protection the decided advantage of wire glass was shown in a number of cases, as that of the Western Electric Company's building. Although the heat shatters the glass, the wire holds the pieces in place in most instances, so that the flame cannot enter; and although it has the defect of diathermancy, even a weak defense inside may overcome the danger arising from the transmitted heat. It has become evident that, in general conflagrations, fireproof buildings are the innocent victims of outside attack rather than the cause. The conclusion is then inevitable that a very great need in improving conditions is adequate protection of exterior openings.

Passing without comment some of the lessons driven home by resulting failures, such as the necessity of adequate and correct connections, thoroughly good riveting, good bond between facing and backing, properly constructed partitions, etc., the general fact is noted (as may be readily seen from the views already shown) that terra cotta offers much less effective resistance to fire than does reinforced concrete. I can tarry on this lesson only long enough to state that this reference is, of course, only to good materials, well fabricated; and in this connection it should also be stated that critical examinations have indicated grave danger of the gradual scattering corrosion of metal embedded in cinder concrete.

There probably is no more important or instructive lesson to be drawn from this disaster than the imperative necessity of adequate protection of essential metal, whether this metal be a steel frame or steel reinforcement of concrete construction; and a considerable advance has been made in determining with much greater definiteness the details of such requirements. San Francisco's revised building laws, as approved on July 5, 1906, permit of the use of brick, metal lath and plaster, terra cotta and concrete. Brick of proper quality furnishes good protection if the minimum covering of the most exposed metal is at least 4 in., and the mortar is of Portland cement. Metal lath and plaster may, with care, be made efficient, but the wisdom of its permissive use seems to the writer to be doubtful, because the requirements for efficient resistance are so easily

slighted; the fact remains that a noticeable proportion of failures in San Francisco were due to a sham application of this kind of protection.

When terra cotta is used, the minimum protection should be at least 2 in. for beams and girders and 4 in. for columns, with especial attention given to proper mortar and to metal ties. It must also be remembered that, where the heat is great, the outer web of terra cotta blocks shears off and falls, due to the excessive differential expansion of this outside web even when water from fire streams does not add its rupturing effects by cooling suddenly the highly heated surfaces; this usually means the preservation of the integrity of the steel frame, but does necessitate an entire reconstruction and replacement of the ruptured terra cotta.

Concrete or reinforced concrete of good quality both protected the structural metal and usually avoided the necessity of reconstruction (because the injury to it was superficial, not radical), except when the thickness of this protection was insufficient. In cases where the embedded, protected steel reached within an inch or so of the surface, the fire conditions often ruptured off the thin protecting layer of concrete, leaving the steel exposed. This is especially liable to occur on the under side of floor-beams and girders, where the embedded rods are so near the surface that the highly heated covering differentially expands considerably as compared with the concrete above the steel, leaving an easily ruptured section in the plane of the reinforcement where the bars are so numerous as to greatly reduce the area between them of the concrete connecting this outer protecting layer with the mass of concrete above the reinforcing steel.

It is believed that 3 or 4 in. of covering for the metal is as necessary for reinforced concrete construction as for column coverings of brick or terra cotta in order to give columns adequate fire protection. Tending to confirm this opinion is the fact that as a general proposition, in a temperature of 1200 to 1500 degrees fahr., heat will penetrate concrete to a depth of 2 in., enough to raise its temperature to 500 degrees fahr. in less than an hour, while it takes perhaps three hours for this temperature to penetrate 4 in.; this is significant because noticeable loss in strength occurs at about this temperature, which increases rapidly for higher temperatures. For evident reasons the regulation of the item just mentioned must be covered by the building laws of cities in order that it may be made

effective, as in the case of so many general requirements necessary for the public safety and welfare.

Hitherto it has been considered that a point of especial vulnerability is the lower flanges of beams and girders. While this fact essentially remains true, it seems that, relatively, more attention must be given to the adequate protection of columns, inasmuch as the failure of one of the lower columns involves not only the loss of it, but also the letting down or destruction of everything above it. The most prevailing cause of destruction and loss in the San Francisco fire, caused by a single class of weakness developing, was due to the partial or complete failure of basement or lower story columns exposed to the fire by the destruction of their fireproofing.

I would add, in closing, one reference that concerns engineering in its commercial and business relations. The adequate protection of essential members from fire will add a small per cent. to the cost of a building over its cost if partially protected. This amounts to a few thousand dollars, which looks large to the firm paying for the structure; consequently, as a rule, the firm will take the risk of destruction for the sake of saving this extra initial expense. Were the small additional expense of thorough fireproofing assumed, it would not only decrease the hazard to the owner, but would make the structure a safer risk to insurance companies. Unfortunately fire insurance companies will not make public such statistics as they have, giving relative losses on different types of buildings. Yet it is believed that their relative losses on buildings of the first class are much less, proportionally, than is indicated by the somewhat lower insurance rate now prevailing for such buildings. In other words, the reduced hazard secured by thorough fireproofing and fire protection ought to secure to the owner an insurance rate so noticeably lower that this saving would go far toward compensating him for the extra expense in securing this increased safety. This reduction in rates might well be made still greater when fireproofed buildings are compactly grouped, thus mutually protecting one another. Engineers, architects, insurance men and men of business would probably find that united consideration of this subject would lead to a mutually beneficial adjustment of these interests on the lines indicated.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, 31 Milk Street, Boston, by May 15, 1907, for publication in a subsequent number of the JOURNAL.]

THE CONCRETE BLOCK AND ITS ADVANCE TO THE POSITION OF A FIRST-CLASS BUILDING MATERIAL.

By Clarence M. Barber, Member of the Detroit Engineering Society.

[Read before the Society November 30, 1906.]

Concrete was used in important engineering work many years before it rose much above the subaqueous foundations of heavy bridge piers, or the footing courses of masonry structures. Gradually it ascended from this lowest position among structural material. Instead of the bottom course, down deep in the earth, it displaced the heavy dimension stone and took its place as the proper material for bridge piers and retaining walls.

Very slowly, indeed, reinforced concrete came to the front. It was some time before the engineering profession realized how admirably concrete and steel mutually reinforced each other when properly proportioned in a beam or column. Of course, proper engineering data were not at hand. Gradually, little by little, these were supplied; then, aided by steel reinforcement, concrete, rising above the pier and abutment, boldly spanned the openings between them and took a new place in the confidence of the whole engineering profession.

The properties of cement were studied by the most noted engineers, and it was soon utilized in almost every kind of static construction. At the present time reinforced concrete construction is going forward at a rate that is marvelous.

The structures that are growing into being every hour, that are rising high above the older buildings, many of them with imposing grandeur, mark a change for the better in the construction of certain classes of buildings that very few of us can realize. Rapidity of construction, moderate cost, strength and durability alone would win, but we must add the fact that concrete is the only building material that successfully stands up in a great conflagration.

Reinforced concrete is peculiarly adapted to the construction of beams, columns and floors. It is sometimes used for walls, but more often the continuity of the structure is broken by the use of other material.

The concrete block is a form of this material adapted to the construction of walls. From the earliest history walls have been

built of blocks of hewn stone or molded from clay. The outward appearance of the wall and the comfort of the dwellers inside have always been characteristic of the material of which the wall was made.

Concrete building blocks have been made and successfully used long enough now to develop their strong and weak points, and to supply some useful and reliable data. Their use has extended so rapidly that they are now in contact with conditions that demand improved quality.

Concrete blocks were invented in a crude way many years ago. But it was necessary for them to come somewhat into use before the conditions which had to be met were known and the defects could be corrected.

The advantages of a hollow block wall were at once recognized as an advance over the solid brick or stone walls in use. The fact that concrete ordinarily absorbs water as readily as brick induced a number of inventions which were designed to prevent dampness from percolating from the outer to the inner face of the wall. Some of these were quite effective. In nearly every block now on the market the matter of preventing water from reaching the inner face of the wall has been considered. In quite a number the inside face of the wall is more or less separated from the outer face. This is notably so in what is known as the two-block systems, where the outside and inside of the wall are composed of two separate blocks. These generally are of the L, T or triangle shapes, which bond with each other on their horizontal joints. In one case the two blocks forming the inside and outside are entirely separated except for small bent anchor bars built into the blocks, holding them apart. In another case a stratum of waterproof compound of a coal tar or asphaltum nature in the middle of the block hygrometrically insulates the inside half of the block from the outside. Several of these accomplish the purpose intended, viz., the preventing of moisture absorbed into the outer face of the block from passing through and appearing as dampness on the inner face. Of course where furring and lath are used the moisture absorbed by the block, which is no more than is usually the case with brick or stone, will not cause the plastered wall to be damp.

In all of the above, while the inner face of the wall is protected, which, of course, is extremely important, the outside face absorbs moisture from rainstorms, and being of a color which shows dampness, it often presents a disfigured appearance after a prolonged rain.

Concrete can be made practically waterproof by making the aggregate as dense as practicable and using about one half as much cement as sand. It is also claimed that a little thoroughly hydrated lime is an advantage. In the case of blocks, however, the quantity of cement required for a 2 to 1 mixture in the body of the block is generally prohibitive on account of its cost.

The most recent and, we believe the best method is to make the body of the block of a good strong concrete with properly graduated sizes of pebbles or broken stone and sand, together with cement enough to make a thoroughly strong concrete and then face the block with a thoroughly dense and waterproof mixture made by using 1 to 2 cement and sand and 1 per cent. of a good waterproof compound. This protects not only the inside face but the entire block, and practically no moisture is absorbed even by the outer face.

A glass of water inverted on the smooth face of a block will hold the water for weeks with practically no absorption by the block. The writer has had a glass of water inverted on a piece of a block that stood on his mantel 40 days. At the end of this time the water escaped, due almost entirely to the expansion and contraction of the air in the glass above the water from changes in temperature.

Within the past year the tamping of concrete blocks by the pneumatic hammer has been introduced in many large block factories. As the material is thrown into the molds, it is hammered home by a shower of 500 blows per min. from a rammer driven by compressed air about 100 lb. per sq. in. This gives a greater density to the concrete than is possible by any other method of ramming, and makes it more homogeneous.

Some of the advantages claimed for concrete walls are as follows:

A dry, hollow wall, which is certainly the most desirable for all kinds of habitable buildings.

The outer face of the concrete blocks can be made in desirable architectural designs of greater variety and at less expense than any other building material.

It requires no paint and never decays or becomes unsanitary.

It resists fire better than any other known building material.

It is cheaper than any other material of its class.

It has been argued that a perfectly waterproof wall would not make as desirable a dwelling as one that is more porous and will permit the diffusion of air through the wall. The hollow spaces in a properly constructed concrete wall are connected

both horizontally and vertically, and in dwellings this inner space is ventilated by a few openings in the basement and attic, so that while the outer face of the wall protects it from moisture from without, the inner face being more or less porous, permits diffusion into the interior, thus giving the advantage of a porous wall as far as the inside is concerned.

In the manufacture of concrete water plays an important part. The amount required varies from about 9 to as high as about 18 per cent. In the setting of concrete the water enters into chemical combination with the other elements, forming, according to Le Chantelier, crystalline calcium hydrate and hydrated monosilicate.

It is convenient and, we believe, consistent with well-founded theory to consider the combined water as the water of crystallization. Following this theory we may think of the setting as the forming of crystals and think of the particles of cement as throwing out acicular arms in every direction, which interlock and hold fast to each other. According to this theory, then, the setting and hardening of cement is not a drying process, but a crystallization. When all of the water required for the complete crystallization and no more is present it will be all taken up and the concrete will be dry. If the water required to complete the crystallization is not all present the formation of crystals will be arrested before they are fully developed. Then if water be again supplied, the final setting will not be the same as if the setting had not been interrupted.

It is extremely important to the proper setting of concrete, if the best results are to be obtained, that it be protected while the process is going on from the wind and sun, especially in dry, warm weather. The dry air will rob the sharp corners and even the faces of their moisture, and a later wetting will not repair the damage.

In a well-equipped concrete block factory, the freshly made blocks are kept for a time in rooms where the atmosphere is saturated with moisture, and generally a sufficient quantity of steam is admitted to hold the moisture above the dew point. This treatment gives sharp, hard corners and edges to the blocks; and, together with a little heat, it hastens the setting.

As to fire-resisting properties. When concrete, which has been fully set, is heated to the boiling point of water, the water of crystallization will not vaporize. It must be heated to about 500 degrees before the water begins to come off, and dehydration is not complete until 900 degrees fahr. is reached. Mr. Spencer

B. Newberry, who is probably one of the best authorities on the subject, states that cement concrete derives its capacity to resist fire from its combined water and porosity. He gives 18 per cent. of the cement contained for the amount of water which a mixture of cement with three parts of sand will take up. The vaporization of the water absorbs heat and keeps the mass for a long time at comparatively low temperature. The porosity of concrete also gives great resistance to the passage of heat. In a fire the outside of the concrete may reach a high temperature; the heat only slowly and imperfectly penetrates the mass. Professor Norton, in his report on the Baltimore fire to the Insurance Experiment Station, says:

"Where concrete floors, arches and concrete steel construction received the full force of the fire, it appears to have stood well, distinctly better than the terra cotta." Again, the same author says:

"When brick or terra cotta are heated no chemical action takes place, but when concrete is carried up to about 1000 fahr., its surface becomes decomposed, dehydration occurs and water is driven off. It would take about as much heat to drive the water out of this outer 0.25 in. of concrete partition as it would to raise that 0.25 in. to 1000 degrees fahr. Now, a second action begins. After dehydration the concrete is much improved as a non-conductor and yet through this layer of non-conducting material must pass all the heat to dehydrate and raise the temperature of the layer below, a process that cannot proceed with great speed."

In the coloring of blocks some very good and acceptable work has been done, but as far as our observation goes coloring has not been entirely satisfactory. Colors with the ordinary pigments seem to fade in almost every case. The effect of the cement is a matter to be considered. It was a surprise to the writer to see in a block factory which he visited at Cleveland a beautiful brown stone and to be told that another near it of a different shade was colored precisely the same and that the difference was simply a question of a few months of age. Of course there are plenty of materials that can be safely used to color the faces of blocks, but they are to be selected with the greatest care. Mr. P. B. Beery, in the *Engineering News*, says that coloring should in all cases be made from the best metallic oxides, free from sulphur. As a matter of fact, blocks can and will be successfully colored, but the problem is not as simple as it at first appears.

One of the difficulties that has caused some embarrassment to block makers in the past has been that it was not easy in every case to produce fractional and unusual sizes of blocks. This has been in a great measure, if not entirely, overcome by the improvements on the block machines. The variety of blocks that can be produced and the flexibility of machines have been greatly increased. As the concrete block takes a more advanced position and better and more complete drawings are used, there should be no more trouble in this kind of construction than in any other. In fact, special blocks can generally be produced as quickly as they are required.

Concrete blocks were used first for foundations and basement walls, but like other forms of concrete construction, they quickly advanced to the superstructures, and to-day we see concrete block buildings going up in our large cities, practically all over the United States. In its progressive movement the concrete block has already gone beyond the cottage and smaller residence buildings and extended to churches, large apartment houses, banks and business buildings.

The concrete block has not yet reached the highest degree of its development, but it has progressed far enough, we think, to demonstrate that its use will continue to extend and the prominence which it has already attained will gain for it still more confidence among the best engineers and architects, and that it will hold a still more advanced position as a first-class building material.

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TO THE MEMBERS OF THE MONTANA SOCIETY OF ENGINEERS:

Gentlemen, — Another year has rolled around since our last annual meeting and a new year sits upon the throne. How often have we spoken of that last year's gathering at Lewistown. We were royally received and entertained by the citizens of that flourishing city, and Kendall and Gilt Edge as well. Every member of the society who was fortunate enough to be present looks back with pleasure to the three days we spent in Fergus County.

It is a pleasure to look back over the year just passed and to see how much has been accomplished in our own State of Montana by the members of this society. The civil, mining, mechanical, metallurgical, electrical and hydraulic engineers have one and all taken an active and important part in the advancement and development of our great state.

The society has not escaped the Grim Reaper. During the past year death has claimed three members of our society. We have been called on to mourn the loss of Mr. Thomas T. Baker, one of the old-time members of the society, and one of the pioneers in engineering work in Montana; Mr. George H. Robinson, also one of the older members of the society, a mining engineer of large experience, both well and favorably known; and Mr. Charles W. Leimer, one of our younger members, a man devoted to his profession of mining engineering.

The year 1906 has taken wonderful strides in all branches of engineering work. The forces of nature have yielded more and more to the engineer as he has delved more deeply into her secrets. All over the world are seen large enterprises under the management of engineers, and certainly Montana is not behind in the general advance. New ideas and devices have passed through the trying experimental stages and have been incorporated in the general scheme for improvements in mining, metallurgy and other engineering branches. It is my intention in this paper to mention some of these improvements, more especially in mining and treatment of ores.

Perhaps the most far-reaching enterprise in the state is that of irrigation by the Reclamation Service under the Department of the Interior. Four irrigation projects are under way in Montana.

Milk River Project.

Preliminary work has begun on this project. Surveys have been made, office buildings erected and right of way for canals cleared. This project will ultimately reclaim 175 000 acres at an estimated cost of $4 500 000.

Huntley Project.

This project contemplates the reclamation of 33 000 acres of land located along the Yellowstone River in southeastern Montana, within the ceded portion of the Crow Indian Reservation, between Huntley and Bull Mountain Station. The lands reclaimed are along the Northern Pacific and Chicago, Burlington & Quincy railroads. They form a portion of the area which the Crow Indians, by treaty ratified by Act of Congress, approved April 27, 1904, ceded to the United States. Upon completion of allotments to the Indians, as required by the act, the area remaining is to be subject to disposition in accordance with the provisions of the homestead laws and the rules and regulations governing the disposal of public lands. The President of the United States will issue a proclamation giving notice when the lands will be thrown open to general entry.

Surveys have been made to outline a comprehensive system of irrigation for a portion of these lands, which will necessitate the construction of a main canal 40 miles in length. Contracts have been awarded for the construction of divisions 1, 2 and 3 of the main canal, for the necessary structures on the canal for distributing system of laterals and for a telephone system.

In addition to the cost of reclamation, the price of the lands is to be $4 an acre when entered under the homestead laws.

This project is about 60 per cent. completed, and it is expected that some water will be delivered to lands under it in the present year. The cost will be about $900 000.

Sun River Project.

This project was formally approved by the Secretary of the Interior on March 9, 1906, and the sum of $500 000 was allotted for initiating work of construction. The preliminary investigations indicate that in the valley of the Sun River, 256 000 acres are reclaimable, a large percentage of which is public domain. The irrigable area is a broad prairie extending from the Teton River on the north to Sun River on the south, a distance of 30 miles, and from the Rocky Mountains on the west to the Missouri River on the east, a distance of 70 miles.

The land, although extremely rich in all the elements of fertility, without water is only fit for grazing, but when irrigated will be very productive. The examinations made by the engineers show that this project is free from difficult engineering features, and the topography of the country is such that it can be built a unit at a time. It is possible that the first unit selected for construction will be the reclamation of about 16 000 acres.

The Lower Yellowstone Project.

This project contemplates the diversion of the waters of the Yellowstone River, — at a point 17 miles northeast of Glendive, for the irrigation of 66 000 acres of land lying in northeastern Montana and northwestern North Dakota.

The public lands available for homestead entry should, at the proper time, be filed upon through the land office situated at Miles City. The lands to be affected by this system are tributary to the Northern Pacific Railway line, which passes through Glendive, 19 miles from the head gates, and the Great Northern Railroad, which has a station at Buford, 2 miles from the lower end of the project. The probable size for farms on this project will be 80-acre tracts.

Work is in progress on the main canal and lateral system.

This project is well under way and water will be delivered under it in 1908.

When these four projects are completed it is estimated that they will cost over $13 000 000, and that about 500 000 acres will be reclaimed.

Railroads.

The Chicago, Milwaukee & St. Paul Railway Company has done an immense amount of grading and preparatory work on its road through Montana to the Pacific coast. The company is not inclined to give out any definite information, but from various sources, including statements in the newspapers, which are credited as coming from the president of the company, we are able to get a general idea of where the road will be located.

Roughly speaking, it parallels the Northern Pacific Railroad, although in some parts of the state, as in the eastern part, there is considerable distance between them, but in other places they run together for long distances and cross each other numerous times.

The St. Paul Railway enters Montana 25 miles north of the South Dakota line and extends in a northwesterly direction to Fallon. It crosses the Yellowstone River at Terry; then follows up the Yellowstone to Miles City, and from that place to Forsyth, where it leaves the river and goes in a northwesterly direction, crossing the divide between the Yellowstone and Musselshell rivers. It follows up the Musselshell to Harlowtown, where connection will be made with the Montana. From Harlowtown it goes over the divide to Sixteen Mile Creek and thence to Lombard. At Lombard the Northern Pacific Railroad will be crossed overhead and the Missouri River by a six-span bridge 600 ft. long, and the Missouri River followed to the Jefferson; thence the Jefferson to Whitehall. At Whitehall the road crosses the Continental Divide by way of Pipestone Pass to Butte at a maximum elevation of 6 350 ft.

A large force of men is at present at work on the divide between Whitehall and Butte. Two tunnels aggregating about 3 700 ft. will be driven and several high steel trestles will be made use of in this part of the work.

West of Butte the road follows the Deer Lodge, Hell Gate, Missoula and St. Regis rivers to a point near Saltese, where the ascent of the Bitter Root Mountains begins.

The company promises to have trains running into Butte by January 1, 1908.

Northern Pacific Railway Company. — Mr. F. J. Taylor, division engineer, states that there was no new work built during the year, the main work being improvements and betterments of the main line. There is under construction at present 12 miles of double track running west from Livingston, and a contract has just been let for constructing 75 miles of second

track between Garrison and Missoula, and work on same is just being started. On both of these lines considerable divergence from the present line has been made for improving the alignment and grade.

Oregon Short Line Railroad Company. — Mr. Wm. Ashton writes there has been no railroad construction in Montana during the year 1906. The survey of the Yellowstone Park Railroad enters Montana from Idaho over Ray's Pass; the distance from Ray's Pass to the proposed terminus of this line on the boundary of the Yellowstone National Park is 20 miles. This line of railroad is under construction south of Ray's Pass, and it is now expected that construction between Ray's Pass and Yellowstone Park will be completed early next season.

Statement of Engineering and Improvement Work Carried out on Great Northern Railway and Operated Lines in the State of Montana during 1906.

Mr. J. C. Patterson, assistant chief engineer, writes that the improvement work on existing lines during the year was perhaps not of the magnitude of previous years, but at the same time there was a general advance in the condition of the railway, and a large amount of engineering work has been performed and is still in progress, looking to improvements in the future, especially in the way of reduction of the present rates of grade and revisions of location.

There were 67 miles of track extending east from Havre on the main line relaid during the season with 85-lb. steel rail, using Wolhaupter joints and tie plates, this replacing rail of a lighter section. In this territory the old main line switches were replaced with others of an improved pattern, and the work in general carried out with a view to caring for an increased traffic and the handling of heavier equipment.

In the way of replacing timber bridges with permanent structures, the most important work was the erection of a new steel bridge over the Missouri River at Great Falls, which work was successfully completed during the year. This structure is of a total length of 1 044 ft., composed of steel deck girders, 13 spans 80 ft. long and one 40 ft. It is supported by 13 piers and 2 abutments, founded on bed rock and composed of first-class masonry to the amount of 1 250 cu. yd. of sandstone secured from quarries adjacent to Great Falls. There are 550 tons of steel in the structure. To avoid interference with traffic the new bridge was erected on a line parallel to the original

track, on the upper side of the old bridge, so that the new structure was entirely completed and put in operation before any change was made in the old one.

Continuing the work of replacing timber bridges by permanent structures, work was started during the season on the Montana Central Railway of replacing with steel three crossings of the Prickley Pear Creek between Helena and Clancey, and three crossings of the Boulder River in the vicinity of Basin. The masonry work for these structures is sufficiently advanced to admit of the entire work being completed in the early spring, when some 600 lin. ft. of wooden bridges will be replaced by 437 lin. ft. of permanent steel structure.

To care for the demands of operation there were laid out and partially constructed during the year, within the limits of the state, 19 miles of additional passing tracks.

For the protection of traffic and safety of operation there was installed an electric staff system of block signalling at the Boulder Tunnel, and a further extension of this system between the terminals at Butte and the yard at Woodville is now being constructed.

Construction of New Lines.

The only work of this nature within the limits of the state has been expended upon the construction of the Billings & Northern Railroad, which is to connect the Neihart Branch of the Montana Central Railway at Armington, and the Northern Pacific and Burlington railways at a point on the line of the former about 11 miles west of Billings and 3 miles east of Laurel. The total length of the new line is 194 miles. The general course of the line from Armington is southeast, extending through the easterly portion of Cascade County and passing through portions of Fergus, Meagher and Yellowstone counties. The line, leaving the Belt Valley at Armington, follows up over the course of Otter Creek on an equated 1 per cent. grade; thence over an undulating country, crossing the divides or watersheds between Otter Creek and Arrow and Judith rivers, to the well-known pass between the Little Belt and Big Sandy mountains, commonly called the Judith Gap, at which point an elevation of 4 060 ft. above sea level is attained; thence gradually descending along the waters tributary to the Musselshell River, and thence over some intermediate divides down into the valley of the Yellowstone River at the point of connection with the Northern Pacific Railway. The maximum grade, other than that of the 12-mile

ascent up Otter Creek, is an equated 0.6 per cent. maximum curve, 4 degrees, of which, however, there is only one, the balance of the location being based upon the use of 3-degree curves or less. The limitations of grade and curvature imposed and the desire to obtain a thoroughly first-class line have led to the adoption of a line that will involve heavy construction expense. The estimated grading quantities will amount to 10 017 000 cu. yd., of which it is expected that 25 per cent. will be of higher classified material than earth. The total degrees of curvature is 6 202. The percentage of tangent or straight line to the total length of line is 73. There will be 4 tunnels of an aggregate length of 6 580 ft., the longest of which will be 2 400 feet, and the shortest 1 100 ft.

Considering the character of the topography and the large drainage areas passed over, the amount of temporary or timber bridging is comparatively small for the total length of line to be constructed. This condition has been partially brought about by the adoption of the plan to provide on the original construction as large an amount of permanent embankment as may be possible. The linear feet of bridging as now laid out is 19 600, requiring the placing of 500 000 ft., board measure, of timber. The longest bridge is at the crossing of the Musselshell River; this is to be 800 ft. in length, and provide not only for a crossing of the river, but also for an overhead crossing of the Pacific extension of the Chicago, Milwaukee & St. Paul Railway.

The work on the grading was started in June last, and up to date of November 30 there had been moved 3 396 000 cu. yd. of material — approximately 34 per cent. of the entire amount required. Great difficulty was encountered during the past season in the way of maintaining a suitable force, as on account of the large amount of improvement and construction work in progress throughout the country labor was very scarce and difficult to obtain. The maximum force employed at any one time during the past year was 1 500 men, 970 teams, 28 grading machines and 6 steam shovels. It is expected that a larger equipment will be employed during the coming season and the entire grading work completed, at least, by August 1.

The track will be laid from both ends of the line, with the use of 85-lb. steel rails in 33-ft. lengths, Wolhaupter joints and steel tie plates. The track will be fully ballasted and the line equipped with water supply, station and track department buildings, the right of way completely fenced and terminal facilities provided, the expectation being that the work will be

fully carried out and the line put in operation during the present year.

Mining.

During the past year mining has been unusually active and the mining engineer has been more than busy. The old companies have kept up to their record and many newly organized companies have added to the general development, especially of the Butte district. Numerous shafts have been started on more or less promising locations, and we all hope that they will all strike pay ore. The deeper mines have opened up still lower levels, and one shaft, the High Ore, is 2 600 ft. deep, with several other shafts not far behind. The various levels have been extended in all directions and numerous new connections made with adjoining mines, thus improving the ventilation of the mines and increasing the facilities for escape in case of accident.

I wish to testify to the care and accuracy of our mining engineers; they do not make mistakes. In all the many connections made between the mines belonging to the same company, or to different companies, I do not recall one where the error was of any magnitude, and generally there is no error.

As a matter of general information it may be interesting to know that the six companies comprising the Amalgamated Company have made an advancement of 22 miles in their drifts and cross-cuts during the year 1906.

The outlook for the future was never better for Butte from a mining standpoint. The lowest levels of our big mines show good values and large ore bodies.

This coming year still lower levels will be opened up and new ore bodies, or a continuation of the old ones, will be exploited. Thus do we add to our reserves by prospecting as we take from our reserves by stoping.

Butte's underground city is steadily growing; the streets and alleys, during the working hours, are sending a steady and ever-increasing stream of ore to the various shafts to be hoisted and shipped to the smelters where the yellow, white and red metals are extracted to add to the wealth of our great mining camp.

At several of the mines, notably the Mountain View and Leonard, larger engines have been installed, and skips have taken the place of cages to handle the increased tonnage.

At the Leonard Mine a new four-compartment shaft has been sunk and an up-to-date surface equipment installed. As it differs somewhat from others a short description may be interesting.

The structural steel head frame is now a part of the equipment of all modern hoisting plants in Butte and considerable improvement is noticeable in its construction. The steel skip bins and automatic dumping skips are among the first additions to this style of frame and the manner of dumping the skip shows decided improvement. Instead of a latch on the skip and a trip to dump it, a gap is cut in the steel guide wide enough to allow the shoes of the skip to pass through and the wheels of the skip to follow the curve into the bins, thus eliminating any danger of the skip dumping in the shaft and causing damage.

A decided departure from the older head frames in Butte is noticeable in the new steel head frame, much less material being used in its construction than formerly, and by this change of design a frame has been constructed equal in every particular to the others and at a large saving in cost, thus showing that we have been using altogether too much material in this class of construction. The general dimensions and a general description of this frame are as follows: Height of frame over all, 153 ft.; height from base to center of sheave, 141 ft.; distance from front to rear columns at base, 68 ft.; distance between columns (front and rear), 47 ft. 6 in.; its main members are constructed of two 12-in. 20.5-lb. channels and one cover plate $\frac{5}{16}$ in. by 16 in., the other side consisting of lattice straps riveted to the channels (the main members of older frames being constructed of two 15-in., channels 33 lb., and two cover plates, each $\frac{3}{8}$ in. by 20 in).

The main struts consist of two 15-in. channels with lattice iron straps riveted on the top and bottom sides; the braces consist of 8-in. and 10-in. channels and lattice iron straps; the gusset plates are only large enough to allow a proper connection of the members. The bottoms of the main members or posts are securely fastened to each other by struts connecting the front and rear columns, also struts connecting the front columns with each other and the rear columns with each other. These members are constructed of two 12-in. 20.5-lb. channels with lattice straps on the top and bottom sides. These members were omitted in the older steel frames, which has proved a serious defect where the ground around the shaft is moving. The bases have spread so far apart that the main rear columns have both been broken, as in the case of the old steel frame at the Leonard. In this case the anchor bolts on the front columns have been removed, allowing the ground to move without carrying the columns with it, and it would probably be a better plan to omit the anchor bolts on either the front or rear columns where there is any liability of the ground moving, as this would prevent the strain-

ing of the members as is so often the case at present. The material in the new frame is of the grade known as medium steel of a maximum ultimate strength of 68 000 lb. per sq. in. The weight of the frame and skip bins complete is 346 425 lb.

At the same mine, and forming part of the same equipment as the frame above mentioned, has been installed a cross-compound, double drum, first-motion, Corliss type hoisting engine, made by the Nordberg Manufacturing Company, Milwaukee, Wis. This engine is similar to the one at the Original Mine, with a few slight alterations, a better grade of steel being used in the drum, and the drum has also been ribbed, thus strengthening it considerably. The cylinders are 32 in. in diameter and the stroke is 72 in. It is capable of developing 3 000 h.p. With a load of 34 000 lb. (including the weight of the rope), at a steam pressure of 140 lb., it is good for a depth of 3 500 ft. The shaft is 18 in. in diameter; the main bearings are 18 in. by 27 in.; the crank pins are 9 in. by 7.5 in.; the cross-head pins are 6 in. by 9 in.; the drums are 12 ft. in diameter and 5 ft. 6 in. face, made of steel plate 1.125 in. thick, and will hold sufficient 1.5 in. round steel wire rope for a depth of 3 500 ft. Weight of engine complete is 500 000 lb.

As our mines get deeper the ore bodies are generally more distant from the hoisting shafts, and the tramming of the ore becomes a serious problem. For several years we have used many horses and mules in our mines and they have done good work and have lessened, very materially, the cost of tramming. But the horses or mules must give place to electricity. Electric power for haulage purposes was first used experimentally, but it has demonstrated many advantages over all existing haulage methods where the distance is considerable.

Electric locomotives are both durable and efficient, and as a means of conveying power to a distance electricity has many advantages over the other agencies used in tramming, both as to economy and flexibility. The electric locomotive, considered as a machine, has many points in its favor for mine use. It is simple in construction as well as in operation, and for hauling capacity it is by far the most compact of all forms of motive power. Externally the electric locomotive consists of a cast-iron box heavy and strong, nicely adapting it to the required service.

There is a similarity in the general design of the electric locomotives built by the principal manufacturers, the rated draw-bar pull and speed of the locomotive, together with its

weight, determining the normal capacity under ordinary circumstances on a level track in good condition.

The experience with electric locomotives in the Anaconda Company's mines has been very satisfactory. The company has for the past four years used at three of their mines electric locomotives for hauling the ore from the skip chute at the collar of the shaft to the main ore bins. The electric machines have proved themselves reliable under severe treatment.

The locomotives weigh 4.5 tons, have 30-in. gage, and 37-in. wheel-base, single-end control, two 12-h.p. motors, 1 200-lb. draw-bar pull at 500 volts direct current, and a speed of 6 miles per hr. By keeping extra repair parts in stock it requires but a short time to repair any breakdown that may occur. For the surface locomotives the common electric street car practice is followed in suspending the trolley with track return.

On the 2 000 ft. level of the Anaconda Mine there is an electric haulage system that has been in operation and working successfully for about 18 months. Two hundred and fifty volts, direct current, are used in the mine. This is not dangerous to one coming in contact with it. The tramming distance on this level is 1 700 ft. The trolley wire used is a No. 0 hard drawn copper suspended from one side of the cross-cut and is supported about every 30 ft. by clip hangers. These are secured by drilling holes in the back of the cross-cut, then driving wooden plugs in them, to which are fastened the trolley wire insulators. The feeder wire for this system is a No 2–10 copper stranded conductor, rubber covered and braided, with $\frac{3}{32}$-in. lead covering over all. The return for the circuit is made by using old discarded lighting wires and the main air pipe line. Twenty-five lb. rails are used and the track is bonded by using short pieces of No. 1 copper wire wedged into the holes drilled into the web of the rails, the bond wire being located along the outside of the rails beside the fish plates. At starting an extra heavy load there is about 5 per cent. drop in the line. At times some trouble is experienced by oil and wet ore accumulating on top of the rail, causing sparking at the wheels, due to poor electrical connection with the rails. The locomotives are given a thorough inspection about twice a month by an electrician, when the commutators and controller contacts are given a good cleaning.

We have two locomotives made by different firms; both have been given a good trial and both work satisfactorily on an 18-in. track. One locomotive has a 26-in. wheel-base, weighs

2.5 tons, with an 800-lb. draw-bar pull, one 15 h.p. motor connected with the other axle by a sprocket chain.

The other locomotive has a 34-in. wheel-base, weighs 3 tons, with a draw-bar pull of 700 lb. and two motors of 5 h.p. each, one over each axle. The speed of each locomotive is 6 miles per hr., which is certainly fast enough for any underground work in these mines.

The work done by these locomotives has been very satisfactory; they will push or pull a load and we find no difficulty in hauling 15 loaded cars (23 or 24 tons, including cars) on an up-grade. Our grade is generally 6 in. in 100 ft. Ten cars is about the average load, and these are easily handled.

We have not yet branched off from the main cross-cut, but this can be done at any time, and it will be done when the level is sufficiently opened up to make it necessary. The cost for power is small, probably in our mines here in Butte it is less than the amount necessary to keep two horses, and one locomotive will do the work of several horses; besides, in a case of a temporary shut down the expense ceases at once.

Electricity as a motive power for underground work in Butte mines is in its infancy, but this year will see a large increase in its use. The trolley line on the 2 000 level of the Anaconda Mine is the only one in operation underground in any of the Butte mines at present, but both the 1 600 level and the 2 200 level of the Anaconda Mine will have electric locomotives before long.

The Boston and Montana Company are preparing to install electric haulage systems on the 800, 1 100 and 1 400 levels of the Leonard Mine. Other companies will see the advantages of this power in underground work, and they will not be slow to make use of it. We shall have an underground trolley system that will rival the one on the surface.

Boston and Montana Consolidated Copper and Silver Mining Company. — At the Great Falls smelter, of which Mr. A. E. Wheeler is superintendent, no improvements of importance have been made this last year, but for the coming year very important changes have been decided upon.

The Boston and Montana Company decided last year to increase the capacity of the works at Great Falls from 3 000 tons of concentrating ore and 500 tons of smelting ore daily to 4 000 tons of concentrating and 700 tons smelting grades, representing an addition of one third to present capacity.

In order to provide for these enlargements it was first neces-

sary to make plans for more water power, and the company has in view the development of a sufficient amount of power from the falls below the works not only to provide for the requirements of the proposed additional machinery, but also to supply enough power from this source so that steam power will not be required in seasons of low water, it having been necessary for the last several years to develop 3 000 h.p. from steam boilers during several weeks of the summer and early fall.

One of the most important matters in connection with the increased capacity is the building of a new chimney and flues, the present arrangements in this respect being inadequate for the duty required of them; so the company decided to build a very large chimney which would not only provide for the new furnaces already authorized, but would be large enough for all possible future extensions of the works. A contract has recently been let for a chimney 506 ft. high. This chimney will be so placed that the actual height above the surface of the ground will be 500 ft., and the inside diameter at the top will be 50 ft., while at the bottom the outside diameter will be 75 ft. The main wall is 64 in. at the bottom and 18 in. at the top, and a sectional lining is one of the features of the chimney, this lining providing for expansions and contractions. The chimney when completed will weigh 16 600 tons, and will be built of special brick which the manufacturers call "radial or segmental." These brick are also perforated, thereby reducing their weight to a certain extent and providing for a better bond in the construction. A brick plant will be built near the proposed location of the chimney, and this will contain several kilns for the proper burning of the brick.

A flue about 1 700 or 1 800 ft. long and 48 ft. wide will connect the furnaces with the new chimney, and this flue will have an enlargement for about 350 ft. of its length where the flue dust will be collected. The width of this part of the flue will be 175 ft., and provision will have to be made under it for the removal of the dust. The walls of the flue will be built of brick, but it is not yet decided whether the perforated or common form will be used. The contract for the chimney has been let to the Alphons Custodis Chimney Construction Company of New York. This company has built a number of high chimneys in the United States as well as in foreign countries. The highest chimney in the United States at present was built by the Custodis Company for the Offorx Copper Company, at Constable Hook, N. J. This chimney is 365 ft. high and 13 ft. in diameter.

Another large chimney built by this company, 300 ft. by 30 ft., is the one at the Garfield plant of the American Smelting & Refining Company in Utah.

The present chimney, which was built in 1890, has a height of 185 ft. and is 20 ft. in diameter, so the top of the new chimney will be 320 ft. above the top of the present one.

In this connection it will be of interest to compare the new chimney with the one at the Anaconda works. The chimney at Anaconda has a height of 300 ft. and a diameter of 30 ft., with a lining extending to a height of 145 ft. from the base. About 2 200 000 common brick were used in the construction of this chimney, while 5 700 000 common brick would be required to occupy the same volume as the walls of the proposed new chimney at Great Falls when built of radial brick. The top of the Anaconda chimney is 724 ft. above the blast-furnace charging floor, and the top of the new chimney at Great Falls will be 742 ft. above the blast furnaces, thereby giving a slightly better draft than is obtained at Anaconda.

The addition to the concentrating facilities at Great Falls, as stated above, will provide for the treatment of 1 000 tons daily, and experiments are now in progress which will probably lead to the introduction of improvements over old methods now in use at Great Falls and Anaconda, special efforts being made to get greater capacity within a given space by the use of new forms of jigs, such as the Hancock and Woodbury, and by other appliances.

The additions to the furnaces will include one new blast furnace 15 ft. by 56 in., and furnaces Nos. 4 and 5 will be connected in the same way as the Anaconda furnaces are connected, making one long furnace, and the blast-furnace capacity will be increased to the extent of something over 40 per cent.

In the roasting department 6 McDougall furnaces will be installed, making a total of 28 furnaces of this type.

The reverberatory equipment will be increased by the removal of an old furnace 42.5 ft. by 15 ft., and the construction of a new one 85 ft. by 17 ft., and this additional reverberatory capacity will require 8 more gas producers, reverberatory smelting at Great Falls being with gas fuel made from belt coal.

No additional converter stalls will be required, but larger converters, which have already been tried, will be increased in numbers.

Improvements at the Washoe Smelter, Anaconda, Mont.

At the Washoe Smelter, Mr. E. P. Mathewson, manager, the following improvements have been made since the last visit of the Montana Society of Engineers:

Concentrator. — It is the purpose to change the motive power of the concentrator from steam to electric, the steam units being held intact as a reserve. This electric power will be taken principally from the Missouri River Power Company's lines, it generating its current at its new dam and power plant near Helena. The motors to drive the mill are 1 200-h.p. capacity and so arranged on a quill shaft that the mill can be operated by steam or electricity with the least possible trouble. There are four of these motors built by the Bullock Manufacturing Company, and are of sufficient power that any one motor can drive three sections.

Calcine Building. — In this department there have been sixteen 6-hearth McDougall roasters of the Evans-Klepetko type added in the last three years, 8 of which are now under construction with the necessary additional flues and extensions to dust chamber and building. This makes 64 roasters in all, with a capacity of about 45 tons each, a total of 2 880 tons.

Reverberatory Building. — There has been considerable work done in these buildings in the last three years. Originally there were fourteen 19-ft. by 50-ft. reverberatory furnaces with forced draft, each having a capacity of about 100 tons per 24 hr. These furnaces have been dismantled one by one and replaced by furnaces of the following hearth dimensions:

One furnace	19 ft. by 116 ft.
One furnace	19 ft. by 102 ft. 6 in.
Five furnaces	19 ft. by 112 ft. 6 in.

With an additional furnace 19 ft. by 112 ft. 6 in. under construction.

The capacity of these furnaces is 300 tons of cupreous material in 24 hr. on natural draft.

Another decided improvement is the addition of two 375 h.p. Stirling boilers in tandem to each furnace, for the purpose of generating steam from the waste gases. These boilers develop 600 h.p. from the gases of each furnace, reducing the temperature of the gases from 2 800 degrees fahr. to 600 degrees fahr. Another improvement is the treatment of the ashes coming from the grates of each furnace by jigs, saving coke and unburned fuel to the extent of 10 per cent. of the fuel used.

Smelter Power House. — To meet the demands of increased

tonnage and production there have been added to the smelter power house 4 blast-furnace blowers and engines, 2 compressors for converter air, one 900-lb. air compressor for the local tramway, one 90-lb. air compressor and 1 hydraulic pressure pump. This brings the capacity of the blast-furnace blowers up to 360 000 000 cu. ft. of free air compressed to 40 oz. in 24 hr., and 60 000 000 cu. ft. of free air compressed to 16 lb. for converter use. The future construction in this building calls for two electrically-driven blast-furnace blowers and one electrically-driven 900-lb. air compressor.

Briquette Plant. — The rearrangement and improvements at this plant are unique. The original briquette machines have been discarded as inadequate. In their places 4 Chambers Brothers end-cut, auger-type brick machines are used, each having a capacity of 700 tons of material in 24 hr. The materials for the briquettes are conveyed from the storage bins by means of belt conveyors to the pug-mill mixers, the discharge of the mixer feeding to the briquette machine, which presses it through a die in a continuous bar, which is cut by a revolving cutter, peculiar to this type of machine, into briquettes weighing from 10 to 12 lb. The briquettes are conveyed by belt conveyors to small storage hoppers holding the amount needed for the charge. The mechanism of these hoppers is such that the entire blast-furnace charge train can be loaded in an incredibly short time by the single movement of two levers, which operate two shafts, having cams located opposite each hopper. The revolution of the shaft causes the cams to engage the latch holding the door shut, which door forms the bottom of the storage hopper and causes the latch to unlatch and drop the contents of the hopper into the car beneath. The doors are each counterbalanced by a heavy weight, so that when relieved of their load they are brought to their natural position ready for another charge.

Blast Furnaces. — Originally there were five 56-in. by 180-in. blast furnaces. In 1902 two additional furnaces of the same dimensions were added. These furnaces had a daily capacity of 450 tons of charge. In February, 1905, the first step towards making larger units was made by combining two of the 56-in. by 180-in. furnaces, — by removing the ends and filling in the space between, — making the entire furnace 56 in. by 51 ft. This furnace was so successful that two other furnaces were connected in like manner. This left three furnaces of the original size, and to further increase the capacity of the plant, the three were con-

nected as one furnace 87 ft. long. This makes the present equipment to be: Two 56-in. by 51-ft. and one 56-in. by 87-ft. furnaces from the center of tuyeres to the charging floor, with 14 ft. working column. The 51-ft. furnaces have 88 4-in. tuyeres and the 87-ft. furnace 150 4-in. tuyeres. The original capacity of the building with 7 furnaces was about 3 150 tons of charge; the present capacity being 1 600 tons of charge for the 51-ft. furnace and 3 000 tons for the 87-ft., or a total of 6 200 tons of charge. The larger furnace has decided advantages over the smaller; it has increased hearth area with but two ends to bind and hold the crusts, smaller radiating surface for the same hearth area, uses less coke and makes a very flexible unit, as any part of the furnace can be handled as the case demands; it is susceptible of repair without shutting down the entire furnace; in fact, the entire end of one furnace has been shut down, cleaned out, jackets changed, while the other half of the furnace was in operation.

Converter Building. — No extensive changes have been made in this building except the addition of two converter stands and a new slag conveyor in course of construction.

Electric Power. — The company has acquired the power plant of the Montana Power and Electric Company, at Flint Creek Falls, which has Georgetown Lake as a reservoir. The generators are being replaced with a type suitable for the demands of the new works and a pole line put in. It is expected that from 1 000 to 1 500 h.p. will be developed, part of which will be used at the Silver Lake pumping station, which supplies part of the water used by the plant in winter time. This pumping plant has been changed from steam to electrically driven pumps during the past summer; the remainder of the current will be used at the new works. A transformer house has been erected at the smelter,— one end being devoted to the Flint Creek power, with its necessary transformer, switch boards, etc.; also, three 3 h.p. motor generator sets for direct current; the other end for the use of the Missouri River Power Company as a transformer building, it transforming its current from 60 000 volts to 2 200 volts through four 1 675 h.p. Westinghouse transformers.

Flues and Stacks. — On the 13th of February, 1903, the construction of the new flues and stack was commenced and was completed September 11, 1903. The branch flues from the blast, roaster and reverberatory are 20 ft. wide and 15 ft. high, and of brick and steel construction.

The converter flue consists of two 7 ft. by 7 ft. flues; the flues are of the following lengths:

Blast	1 653 ft.
Roaster	488 ft.
Converter	703 ft.
Reverberatory	842 ft.

These flues merge into a "main flue" 60 ft. wide with side walls 20 in. high, and excavated so that the bottom slopes are at an angle of 30 degrees from the horizontal. At the bottom is a tunnel, having a brick arch roof, with hoppers every 10 ft.; from these hoppers the flue dust is drawn. The first part of this main flue is 60 ft. wide, with a brick and steel roof, and 1 200 ft. long. The remaining distance to the stack is 1 112 ft. of flue 120 ft. wide, with a steel roof having No. 9 steel as covering. The stack is of brick, 300 ft. high, 30 ft. inside diameter, with an inside core for a height of 145 ft., and a baffle wall 40 ft. high. The stack was completed in 67 working days. Total number of brick in the stack, 2 222 000; total number of brick mason days, 951; total number of brick per man days, 2 336. Some idea of the magnitude of the flue system may be obtained from the following figures:

Excavation	111 163 cu. yd.
Brick	14 188 000
Steel	1 896 tons.
Cement	9 122 bbls.
Powder	3 751 kegs black.
Powder	22 517 lb. giant.
Men days	114 410
Average number of men per day	440

General. — The record production of copper for this plant so far was made in March, 1906, and was 17 086 961 lb.

Some idea of the magnitude of the plant may be conveyed by the following figures:

Amount of ore that can be treated in 24 hr	10 000 tons
Lime rock from adjacent quarries	2 300 tons
Coke used	650 tons
Coal for reverberatory use	500 tons
Coal for power use	500 tons
Water, gal. per min	35 000
Men employed in and around Anaconda	3 000

Helena Power and Transmission Company.

One of the most important engineering works of the past year has been the construction of the dam and generating plant

on the Missouri River by the Helena Power and Transmission Company, of which Mr. M. H. Gerry, Jr., a member of this society, is manager and chief engineer.

The generating plant of the Helena Power and Transmission Company is located at Hauser Lake on the Missouri River, about 15 miles northeast from Helena, Hauser Lake being the name given to the post office and construction camp, in honor of ex-Gov. S. T. Hauser, president of the company. The plant, under a head of 70 ft., will, when completed, develop 20 000 h.p. The lake formed by the back waters of the dam will extend from the crest of the Hauser Lake dam to the tailrace of the Canyon Ferry dam and will cover an area of about 7 000 acres, inundating a considerable part of the Prickley Pear Valley.

The dam itself is a combined steel and reinforced concrete structure. Abutments and all foundations are of reinforced concrete, resting on bed rock everywhere except in the river bed. Where bed rock could not be found the foundations were made by carrying the excavation down well into hard pan gravel and driving timber piles closely together and placing concrete on top. The dam proper is a steel structure 620 ft. from abutment to abutment, having a slope on its up-stream face of 8.5 to 12. The lower, or up-stream line of plates, is flat and rests on a triangularly-shaped concrete rubble masonry fill, 50 ft. wide and 25 ft. high, extending entirely across the dam. The first series of plates is anchored to sheet steel piling, consisting of interlocking channel bars driven to bed rock and the whole covered with concrete. The next series of plates, extending from the flat plates to the crest, is curved and rests on steel bents 10 ft. apart. On top of the dam is a vertical steel construction, supporting 500 ft. of flashboards 14 ft. high, part of which consist of steel gates operated pneumatically. The upper part of the spillway, or apron, which is 500 ft. long, consists of flat steel plates resting on steel bents. The lower portion is a timber construction of rock-filled cribs, resting on bed rock or closely driven piles. On the toe line of the spillway is driven a line of interlocking channel bar piling to prevent an under-wash from the rear.

During construction of the dam the river was turned through six 8-ft. pipes laid side by side and anchored to bed rock and covered with concrete. These pipes were designed to take the entire flow of the Missouri River, except in spring high water, when the river spilled over the partly finished dam and over a temporary timber apron. The river is about to be shut off by means of six timber gates swung simultaneously into place from

above by hinges. In each large gate is a small gate to be closed after the water has reached the crest and is spilling.

The canal leading from the dam to the head-gates is perpendicular to the dam. It is 240 ft. long, 45 ft. wide at the entrance and 40 ft. deep. It was excavated out of solid rock and is lined throughout with concrete. The water from the canal is brought to the power house through five 12-ft. penstocks for power generators, and three 4-ft. penstocks for exciter generators. The head-gates are of curved steel plates with oak seals, the guides of same being embedded into concrete. These head-gates are operated from worm gears, operated by a motor.

The power house itself is a fireproof skeleton steel structure, filled with rubble masonry walls. It is 212 ft. long and 52 ft. wide, standing perpendicular to the dam. The tailrace and power house foundations were excavated from solid bed rock.

To each of the five penstocks an S. Morgan Smith water wheel unit, governed by Lombard governors, is connected, which in turn is directly connected to a 2 800-kw., 2 200-volt, 60 cycle, 3-phase, revolving field type Westinghouse generator, four of which are installed, and a place is left for the fifth.

The currents from these generators are led through duplicate distant control oil switches to nine 2 000-kw. step-up transformers. The transformers are of the Westinghouse oil-insulated, water-cooled type, and transform the current from 2 200 volts to 70 000, which is the line voltage.

The transmission lines are in duplicate from Hauser Lake to Butte and Anaconda, joining the Canyon Ferry transmission lines at a point near East Helena.

Work on the dam was started August, 1905, the Wisconsin Bridge Company having the contract for the steel dam; all other work being done by the Helena Power and Transmission Company. In the construction from three to five hundred men were continually employed up to the present time. In the neighborhood of 2 500 tons of structural steel and 32 000 bbl. of cement were used. All material was transported by means of horses and wagons over a difficult road, a distance of 12 miles from Iron Siding, a point on the Great Northern Railway.

Hauser Lake, for the past sixteen months, has been the busiest little city in Montana.

From the generating plant a large part of the electrical energy is transmitted to the substation at Butte, Mr. W. L. Miller engineer in charge.

The transformer substation will transform electrical energy

transmitted from the Missouri River, the ratio of transformation being 60 000 to 2 200 volts.

The transformers will be arranged in two banks of three each, the capacity of each of the said transformers being 1 675 kw.; in addition to these six transformers there will be one spare transformer of the same capacity as any one of the six which may be connected to take the place of any transformer if the same becomes disabled. The normal capacity of this substation is about 15 000 h.p.

This substation has a floor area of 450 sq. ft.

The steam auxiliary plant consists of six 500 h.p. Babcock & Wilcox water tube boilers and two 2 000 kw. Westinghouse-Parsons steam turbines. The steam is generated at 200-lb. pressure and 125 degrees superheat. The steam turbines are run condensing, and the circulating water is cooled by means of a cooling tower 23 ft. wide, 81 ft. long and 65 ft. high.

The boilers are equipped with Roney stokers, and are laid out on the unit system, there being three boilers to a battery, and one battery to a steam turbine. Each battery is connected to its own self-supporting steel stack 9 ft. in diameter and 200 ft. high.

The auxiliary steam plant covers an area of 17 200 sq. ft.

Another substation is located at Anaconda, at the Washoe plant, quite similar to the one at Butte, but it has only four transformers and no steam turbines.

General Outlook.

Every citizen of Montana should congratulate himself that he lives in the treasure state. Notwithstanding the advance made in every industry in the state during the last year, the new year starts out with the promise of greater achievements, which will bring greater wealth and power to our beloved Montana.

My address would not be complete if I did not make mention of another industry in which we all take pride, and that is the Montana State School af Mines.

Located as it is on the foot hills west of the city, in the shadow of the Big Butte, overlooking the great mining camp, it is a typical location for a great mining school. The young men have every opportunity to keep in touch with the latest methods of mining and metallurgy. They can see the practical application in the mines and smelters of the lectures to which they listen in the classrooms.

The school is well equipped, and is fortunate in having an able corps of professors, whose success is shown by the class of young engineers that is turned out each year. I have tried many of them, both in the practical hard work of mining and in the engineering offices, and in every case the report of the superintendent or chief engineer has been " he is a good man."

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by June 1, 1907, for publication in a subsequent number of the JOURNAL.]

REINFORCED CONCRETE: ITS LIMITATIONS.

By Carl Gayler.

[Read before the Engineers' Club of St. Louis, January 2, 1907.]

Ever since I have had the honor of being a member of this club, I have made it a rule, whenever I had learned something new or acquired some new experience, to bring it before the club in the shape of a paper, and so now, feeling that I have again "something to say," I enlist your patience for a short hour. Of course the subject is on reinforced concrete; what else could a structural engineer speak about nowadays, when we are in the very high tide of this wonderful material, when wood and steel and cut stone are going out of fashion, when the engineer who is not ready and able to use, intelligently, reinforced concrete for anything in the building line, from a fence to an office building, from a sewer to a railroad bridge, might as well take down his shingle and retire?

The subject before us being "Limitations of Reinforced Concrete," it seems appropriate to begin with "Limitations of this Paper." It will not deal with the whole range of the subject, for then I should in a few hours be speaking to empty benches; no new formulas or scientific investigations will be brought forward, for under the wise laws of division of labor, we designing engineers can leave these safely in the hands of the professors and specialists; you may, or, rather you will, discover other "limitations" of this paper; but then, such as it is, offering some homely truths found in actual experience, some considerations worthy at least to be discussed by you, and also deduced from actual experience, you are asked to listen to the same.

Why is concrete reinforced? Because, the ready answer is, the reinforcement imparts to concrete the inestimable quality of resisting shear and tension, as well as compression. But there is another reason of hardly less importance: reinforcing rods, judiciously placed in the body of concrete, transform it into a monolith. Now the generally prevailing opinion is that concrete itself without reinforcement, in drying, contracts into a monolith, but this is in most cases, at least in the shape in which we generally use the material, not the case. Unless we have to deal with concrete in the shape of a cube, or a globe or a prism of

simple shape, no concrete forms into a monolith, *but into a number of monoliths.* It contracts in drying on what may be called lines of least resistance into several pieces of concrete, separated by more or less open cracks, and it is the fact that this can be prevented by embedded steel rods, properly called "shrinkage rods," in combination with the effect of the reinforcing rods used to resist tensions, that has given reinforced concrete its high place among building materials.

Some years ago we listened in this club to an interesting paper on continuous street-car rails in which the remarkable fact was explained that street-car rails can be made continuous without being damaged or torn apart by changes in temperature, as the friction between the surface of the sides of the rails and the pavement is sufficient to hold the rail in place. Substitute in this last sentence the embedded steel rods for the pavement and the mass of concrete for the car rail, and we have stated the principle of the shrinkage rod. It is the internal stress caused by shrinkage of so many square inches of concrete against frictional resistance of so many square inches of embedded surface of steel.

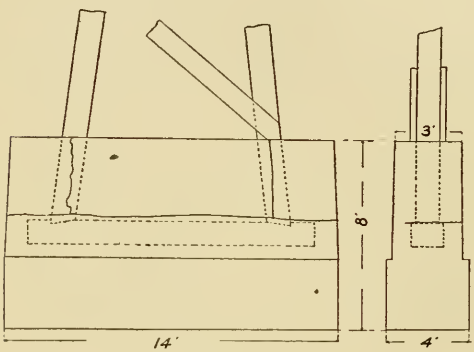

Fig. 1.

Let me give you a few illustrations of the way in which plain concrete in drying separates. The figure before you shows a small concrete pier put up around the base of a wooden trestle bent. The pier being of rectangular shape, about 20 ft. long, 4 ft. thick and 6 or 8 ft. high, might have been expected to form a monolith and would probably have done so if the inclosed timber had not prevented it. You notice the wide crack along the sill and the two vertical cracks along the posts. Two sets of shrinkage rods, one set horizontal to prevent the vertical cracks and another vertical set would have prevented the mischief.

Some years ago, at a time when Portland cement concrete, without reinforcement even, was a new thing, I had occasion to extend the wings of a small highway bridge, using concrete for the extension and stepping it off, as you see in Fig. 2. The

result was a pretty illustration of how such concrete, regardless of the good intentions of the engineer to form a monolith, separates into a number of them. It is hardly necessary to add that the same engineer, to-day, would not design any such graceful stepping-offs, and would probably insert some shrinkage rods.

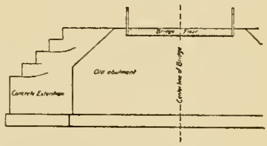

FIG. 2.

Some of you may have had occasion to build a concrete coping with an iron railing on top of it. Now nothing is more natural, or better, than to embed the ends of the railing posts in said coping. But I can state as an absolute fact, observed not only in St. Louis but also in other cities, that of twenty such railing posts, whether they are of cast iron or steel angles, not less than ten will crack a 12-in. or 14-in. coping, 3 ft. to 4 ft. wide at right angles to the line of the coping. The explanation is simple enough; being hindered by the railing posts from contracting into one continuous monolith, the coping contracts into a number of monoliths, each as long as the distance between the railing posts. The remedy suggests itself also. But in this example, insignificant as it may seem to you, we are confronted with another very important problem. If, as we have seen, 10 or 12 in. of 4-in. by 4-in. steel angle, inserted into a body of concrete of 3 to 5 sq. ft. area, are liable to crack the concrete clear across, isn't it apparent that we should look on all embedded reinforcement as, under certain conditions and proportions, an element of weakness instead of additional strength?

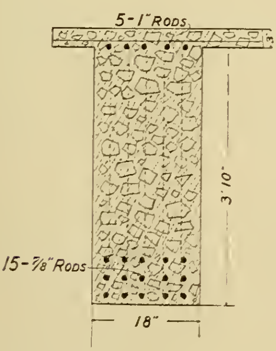

FIG. 3.

We reinforce concrete by steel rods, and we do so successfully with 0.75-in., 1-in., or even 2-in. rods, but what, in view of the above, is the result if we employ still larger rods, or I beams, or steel rails, or, as is daily done in architectural work, if we use a number of small rods, close together, forming a very cluster in a narrow beam?

To illustrate this latter point I have taken at random a section of a reinforced concrete girder from one of the technical journals and shown it in Fig. 3.

I may here remark incidentally, which will also apply to one or two other points brought out later on in this paper, that the architects are in a far more favorable position than we

engineers, since they have a way of plastering, casing in, covering up, in a word, of hiding their work, which we have not. Longitudinal cracks along the reinforcing rods of their girders and beams, and we find here and there mention of such cracks in the publications, do not show in their work.

Now the question is: When have we reached the point where the inclosed metal separates and cracks the concrete instead of being firmly gripped by the same? It is not at all the mere surface contact between the two materials which constitutes the efficiency of the reinforcement, but the fact that concrete in drying shrinks, which shrinking produces its gripping effect on the reinforcement, and it is therefore all important that this shrinking should take place towards the metal, not from it.

It is still customary, although not to the same extent as in former years, to build floors of buildings and viaducts by means of concrete arches between I beams. The centers of these small arches are generally left in position till the concrete is tolerably hard. But the mass of concrete keeps on drying and consequently shrinking, for a long time after; the concrete is generally of too great a thickness to allow of sufficient elasticity to conform to the new span, and the consequence is that a crack forms, either on one side or on both sides of the I beams, *i.e.*, we have not an arch at all but a solid stone, concave below and resting principally on the bottom flanges of the beams. This is no mere theory. I have built hundreds of such arches in former years and hardly ever without meeting with these annoying cracks along the beams. There is a viaduct over the railroad tracks in this city whose floor consists of such concrete arches between 24-in. I beams which carry the street-car rails. Now if during a heavy shower you should be seeking shelter under said viaduct, as has happened to the speaker, you would be glad to have an umbrella over your head. Still, although not perfect, such arches are useful structures and generally answer the purpose very well.

This subject of the shrinking away of concrete from the steel work, instead of clinging to it, is very fascinating and worthy of the closest observation. We have been so educated into the belief that concrete and steel have, so to say, an affinity for each other, that it is not easy to get rid of that impression. Concrete in fact has no affinity whatever for any other material. We all know that it is next to impossible to make concrete join completely a hardened surface of concrete, or masonry or cut stone or any other material, *not excluding steel*. There are a

number of steel plate girder bridges in this city with concrete floors, on which a concrete wheel guard is built up against the web of the plate girders. Surely this is a case where the embedded steel surface should appear to the naked eye as a unit with the concrete, but on a hot sunshiny day you may notice here and there a very fine crack separating the two materials for considerable length.

To sum up:

(1) Concrete in hardening grips embedded steel under conditions which depend on the relative size and shape of the metal.

(2) Concrete in hardening has a tendency to separate from any adjoining surface, due to its own shrinkage. Which rules can be well illustrated, as in Fig. 4.

The above considerations apply to the whole field of reinforced concrete work and furnish, for instance, a strong argument against the Melan reinforced concrete arch and in favor of the reinforced concrete arch where steel rods or bars are so dis-

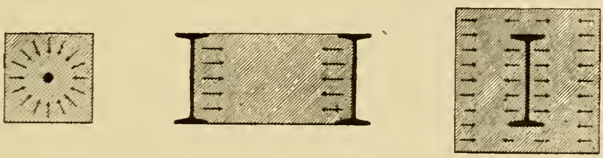

Fig. 4.

tributed over the intrados and extrados that the stresses are readily imparted to the surrounding body of concrete. This is confirmed by the experience of the Passaic River bridge in Paterson, N. J., where the arches in their downfall separated into longitudinal sections along the lines of the I beams. The downfall, however, as you know, was caused by undermining of the foundations during an unusual high water, not through any fault of the system of the reinforced concrete.

But there is another serious limitation to the successful use of reinforced concrete, and this paper has been brought before you in vain if it fails to impress you with its great importance. I refer to the question of proper inspection.

We have, all of us, inspected material, wood, iron, steel, stone, almost any building material used by mankind, but now a problem in inspection has come up such as we never before had to deal with. Assume, to make my argument clear, the case of a steel structure, either the skeleton of a building or a viaduct, and assume further that said steel structure is built without any

inspection, either at the mills, or at the shop, or during erection. Now I will not go so far as to say that the structure will be as good as if built under inspection but it will be *nearly so*. There may be flaws in some of the plates, ragged edges to some of the shapes; there may be here and there a loose rivet; in putting the work together there may be some maltreatment of the metal; some member may after erection be slightly out of line; but after all we shall have a safe, serviceable structure, provided that the plan is correct. Let us now consider the same structure built in reinforced concrete, on a plan equally correct with the plan for the steel work, under the same conditions, no inspection or tests of material, no supervision of the manner in which the rods are placed, more than that whether they are placed at all,— and this is no supposititious case but has to my knowledge been experienced again and again, — no control over the all-important question of continuity of operation, and the plain fact is that we shall not know what we have got at all; we have relied entirely on the honesty and efficiency of the contractor, *i.e.*, we have shirked our duty as engineers under circumstances such as we were never before confronted with. While in the case of the steel structure the possible range between a structure built under thorough inspection and under no inspection is from an excellent structure to a fairly good but at any rate safe structure, the range of the reinforced concrete work under the same conditions is all the way from an excellent structure to absolute destruction.

In confirmation of the first statement I can, from memory, quote Theodore Cooper, who some years ago expressed himself somewhat to this effect: "Every recorded case of failure of an iron bridge (leaving out of consideration accidents through derailments, washouts, etc.) can be explained through faulty designs, never be attributed to poor material or workmanship." If I recollect rightly this was brought out in the discussions arising from the failure of the Tay bridge in Scotland. In confirmation of the second statement we can point to the numerous recent failures in reinforced concrete work.

To illustrate the above-mentioned question of continuity of operation (I like illustrations, they save words and they impress):

Let G, Fig. 5, represent a heavy reinforced concrete girder, B, the beams supported by the same. Now the best method of carrying on such work is to do it uninterruptedly, as far as possible, or, at least, to complete girder G at one time with proper recesses for the beams, and then to finish each beam B at one time.

But take the case that the work is not done on such lines, that the foreman is incompetent or careless, the contractor, as is often unavoidable, absent from the work, — what is to prevent said careless foreman from finishing girder G by itself, without recesses for the beams and to build in afterwards, perhaps after an intervening Sunday, the beams B; or supposing the work done under a glaring sunshine — and I have had cases where I felt like praying for clouds and rain — and the heavy girder G finished to half its height and then let go for a time without troubling about sprinkling,— imagine such and similar conditions, which to a greater or less extent are bound to happen, unless you are lucky enough to have an excellent foreman who relieves you of your responsiblilty, or unless you have the most rigid and intelligent inspection, where is the very safety, not to say excellence, of the work? The success of reinforced concrete work lies in the inspection to a far greater degree than with any other class of building material. And the difficulty and expense of obtaining such inspection, which is generally only to be obtained in government work, municipal work not blighted by politics, or in the thorough organization of railroad work, but seldom in private undertakings or in works built in out-of-the way localities, are in my opinion to be classed among the limitations of reinforced concrete work.

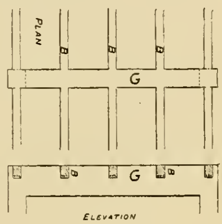

FIG. 5.

Of course, this applies with much less force to foundation work, heavy piers or abutments, etc.

Like the preacher, I might have subdivided this paper into "firstly," "secondly," and so on and the headings would then have been somewhat as follows:

(1) Generally.
(2) Inspection.
(3) Science of reinforced concrete.
(4) Details of construction.

So that we have now reached the problem of the so-called science of reinforced concrete and a very troublesome problem we shall find it, for we are dealing with a material whose physical qualities and even shape undergo great changes for some time after it has assumed its duties, a material the computations of which, more than that, the very definitions of whose properties, are as changing as the winds that blow.

This is a strong statement and needs explaining. I promise

to be as short as possible; the question of shear and the theories of stresses in more complicated structures, as arches, retaining walls, etc., fascinating as they are, will be hardly touched on; instead let us assume the simplest possible case and take up the computation of a reinforced concrete girder, beam or slab composed of ingredients according to ordinary practice, at one particular time, say a few months after the concrete is laid. We have thus discarded the above-mentioned differences in the strength of the concrete at the different periods of hardening, also the question of different qualities of concrete composed of ingredients mixed in different proportions, laid with different amount of wetness, etc.

Now we are all familiar with such definitions as neutral axis, modulus of elasticity, factor of safety, ultimate strength, etc., and we meet them again in the calculations of the reinforced concrete girder, beam or slab, but their character and meaning have changed.

While with steel beams these definitions are definite and constant, with the reinforced concrete beams they are more or less indefinite and variable.

The modulus of elasticity of structural steel is constant within the elastic limit and for the different kinds varies hardly more than 5 per cent. from the generally assumed 30 000 000 lb. per sq. in., but the modulus of elasticity of reinforced concrete is variable, decreasing under increasing pressure, and its variations in strength have been stated at ranges varying all the way from 750 000 lb. to 4 000 000 lb. per sq. in. The generally assumed value of 3 000 000 lb. per sq. in. for the modulus looks like a rather bold compromise. Mr. Christophe, a French authority on reinforced concrete — and it is to the French that we owe our theories on reinforced concrete — suggests the abolishing of the very name of modulus of elasticity of reinforced concrete.

From the fact that the modulus of elasticity of steel is constant while that of reinforced concrete varies, it follows that the neutral axis is variable, rising above the middle of the beam with the increase of the stresses in the beam; and it follows furthermore from the variability of the modulus of elasticity of reinforced concrete, *i.e.*, the variation in the compressibility of concrete, under varying pressures, that the center of gravity of the compression stresses in the concrete varies and also that we have quite a variegated collection of stress-strain diagrams, with which, however, I will not trouble you.

All authorities agree, furthermore, that the term "factor of

safety" is not, strictly speaking, applicable to reinforced concrete work, because cracks open in the lower surface of the concrete before the steel is stretched beyond a safe strain and before the upper part of the concrete is compressed to its safe limit.

Yet, in spite of these uncertainties, variable factors and characteristics, the fact, absolutely proved by daily experience all over the civilized world, remains that reinforced concrete in the shape of beams and slabs, if properly proportioned and handled, is a material of inestimable value, safe, fireproof as no other material, everlasting and relatively cheap; so theories and formulas which covered the case had to be evolved and with an astonishing amount of ingenuity and learning they have been evolved. All honor to the men who gave us these theories. It is true the first formulas looked rather formidable and it was expecting a good deal from the busy engineer that he should familiarize himself with their intricacies. But the long perplexing formulas have had their day and simple rules which appeal directly to the understanding have taken their place.

As you all know, the moment of resistance of a beam, girder or slab is to-day expressed as the product of the stress in the steel reinforcement into the effective height, *i.e.*, into the height from the center of gravity of the steel rods to the center of gravity of the compressive stresses of the concrete, with the condition that the proportion of square inches of steel to the number of square inches of the concrete shall be at a certain ratio. In other words, the moment of resistance of any reinforced concrete girder, beam or slab is strikingly similar to that of any steel girder or beam. Considering the amount of knowledge and ingenuity displayed in the theoretical researches it seems like an unkind saying, but it is true nevertheless, that we are hardly justified in speaking of a "science of reinforced concrete" at all.

It might interest you to see just what cross sections we obtain for a reinforced concrete girder if we apply such formulas and proportions as are the daily practice, and to compare the same with the cross sections of a steel beam and of a wooden joist of the same strength. In Fig. 6 a few such sections are shown, drawn to the same scale.

Assumed units: extreme fiber stress in I beams	16 000 lb. per sq. in.
Extreme fiber stress in reinforcement	,, ,, ,, ,, ,,
Ratio of areas of steel to area of concrete	1.25 per cent.
Extreme fiber stress in wood	1 200 lb. per sq. in.

The results are rather startling and it must be confessed

that for clumsiness, unsightliness and apparent wastefulness the reinforced concrete girder, at least in its simplest shape, is without a peer in the realm of building materials.

In using the word " wastefulness," that part of the concrete which lies below the neutral axis is referred to. It really does seem as if very little use were made of the strength of this portion

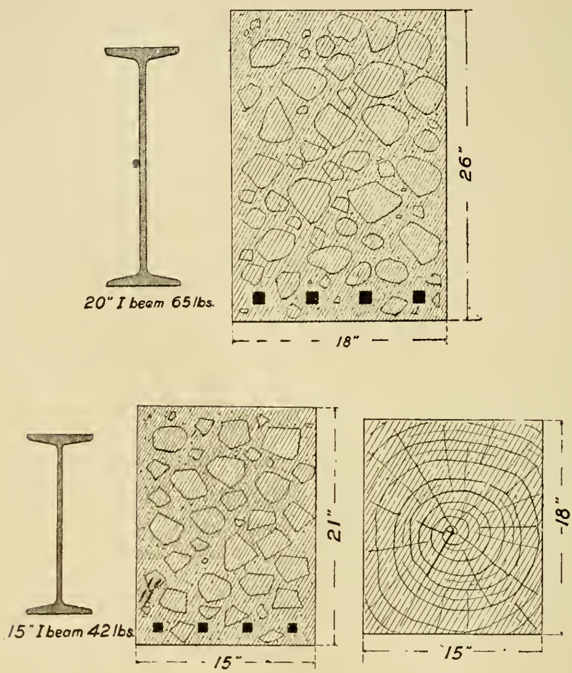

FIG. 6.

of the concrete, at least in girders where the shear is taken up by steel.

In mere fairness it ought to be said right here that the reinforced concrete slab, used as floor for buildings and viaducts, is, in every respect, economy, fireproofness and strength, unequaled by any other building material; but as our subject is the " limitations of reinforced concrete," such a eulogy does not come within its scope.

Let us take another illustration, the comparative cross sections of a column for a building in cast iron, steel and reinforced concrete, all of equal strength. These cross sections are particularly interesting because they are taken from actual experience.

Plans had been prepared for a 5-story warehouse, using cast-iron columns, steel beams and concrete floors. For weighty, financial reasons, reinforced concrete was substituted for all the metal work and the relative cross sections of the cast-iron columns and of the substituted reinforced concrete columns, the latter, as planned by the contractors themselves, drawn to the same scale, from the first story of said building, are shown in Fig. 7. A section of the Z bar column of the same strength is added.

The unit compression of the concrete was assumed at 500 lb. per sq. in., of the reinforcing rods at 7 500 lb. per sq. in. The

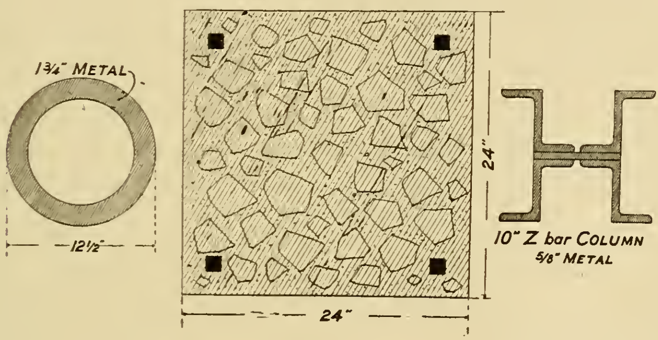

FIG. 7.

sections of the cast iron and of the Z bar columns were taken from Carnegie's handbook.

Allowing 400 lb. per sq. in. on the concrete, instead of 500, would require a column 27 or 28 in. square.

From this and similar examples, taken from ordinary daily practice, I am absolutely convinced that the reinforced concrete column will never be a serious competitor of the steel columns for high buildings, unless we can produce a concrete far superior to the concrete we are using to-day. The steel column, protected by concrete against fire, will remain the best and safest column for high buildings, not only because it is safer and takes up less room but also on account of its elasticity, which enables it to resist tornadoes and earthquakes better than any other known material.

If the use of reinforced concrete for certain parts of structures, as we have seen in the example of columns of high buildings, or of girders where the architectural appearance is of importance, is limited through the competition of steel, so on

the other hand some points can be mentioned in which reinforced concrete is at a disadvantage compared with mason work or cut stone work.

We will not again refer to possible cracks which may occur in spite of all precautions, expansion joints and shrinkage rods, but it is certain that the surface of concrete becomes unsightly through efflorescence, discolored and liable to show a number of fine, so-called hair, cracks. As this fact, however, has been ably discussed by other engineers and as it is very likely that this annoying quality will be successfully eliminated through special treatments of the surface, we will not lay too much stress on it.

But there is another limitation to the use of reinforced concrete which to my knowledge has hardly ever before been brought out, — the low ultimate compressive strength of concrete.

Text-books give the ultimate compressive strength of granite as from 5 000 to 18 000 lb. per sq. in., of limestone from 4 000 to 16 000 lb. per sq. in., of sandstone from 2 500 to 10 000 lb. per sq. in. Prof. Ira D. Baker gives the following list:

Trap rock of N. J.,	ultimate	crushing	strength,	20 000–24 000	lb. per sq. in.
Granite,	,,	,,	,,	12 000–21 000	,, ,, ,, ,,
Marble,	,,	,,	,,	8 000–20 000	,, ,, ,, ,,
Limestone,	,,	,,	,,	7 000–20 000	,, ,, ,, ,,
Sand stone,	,,	,,	,,	5 000–15 000	,, ,, ,, ,,

As the ultimate compressive strength of the different kinds of concrete is from 2 000 to 3 500 lb. per sq. in., this material has to be classed among the soft sandstones. This point is of the utmost importance; it explains the unwieldy size of reinforced concrete columns, also the fact that the surface of concrete has to be protected, particularly at corners, against abrasion, as, for instance, from passing vehicles, heavy floes of ice, etc., and the failure of concrete as a material for street or alley pavements without an extra wearing surface which can from time to time be renewed. There is no doubt that the low ultimate strength of concrete in compression will limit the practicable length of span of concrete arches, whether reinforced or not, and it will also be an important factor in the design of high retaining walls, chimneys, etc.

The time is too short to enter into the question of use of reinforced concrete for retaining walls, but the following statement, based on the experience of many years, may be permitted:

In view of the great uncertainty as to the amount and

direction of earth pressure on a retaining wall, we should always keep in mind that, after all, a retaining wall resists through its bulk, its mass, whether it is built of masonry or of plain concrete or of reinforced concrete. A reinforced concrete wall carefully designed in all its component parts, face work, buttresses, projecting sole and so on, without being ponderous enough to resist the horizontal component of the earth pressure, is like a carefully designed reinforced concrete arch with insufficient foundations.

Taking up the question of details of construction:

Stress has been laid above on the gripping quality of the concrete on the reinforcement, which is indeed the very basis of the success of reinforced concrete construction. Now we find it to be general practice to cover the steel rods in the bottom of a reinforced concrete girder by concrete of a thickness of 1 in. or 1.5 in., and it is customary to consider this as sufficient covering because it is a sufficient protection for the steel in case of fire. This seems to be true; but how can we expect this thin coating to grip the steel rods up to their elastic limit, especially steel rods of an inch and more section? I am aware that this is a matter of judgment and is not covered, to my knowledge, by any theory; but from intimacy with the material it seems to me that a thickness of 3 or even 4 in. for heavy rods would be more appropriate, more particularly so in girders which are exposed to shocks. This applies not only to the beam or girder but to the reinforced concrete arch, the reinforced concrete retaining wall, in fact to any structure where the concrete has to take up the stress or increments of stresses in the imbedded steel work. Let us take, as an illustration, two cases which, though not strictly parallel, are analogous enough to be compared, — the anchor bolts in a pier and the steel reinforcement in the intrados of an arch. We will have the anchor bolts without a washer, because these washers have a tendency to crack the concrete, but held by the gripping effect of the concrete on its surface. Would such anchor bolts be considered effective by any engineer if placed within an inch or two of the edge of the pier, and under what argument or theory are we justified in taking a different rule for the steel rods in the intrados of an arch?

And this brings up another point in the use of such rods: the transmittance longitudinally of their stresses.

In proportioning reinforced concrete columns for a building it is customary to include the sectional area of the steel rods placed near the corners of the column as effective against com-

pression, and it is also customary to make such rods of the length of one story without any connection with or any bearing on the rods in the columns of the next story, *i.e.*, the tiers of columns are so built that the ends of the reinforcing rods press on concrete.

We find this point, however, fully covered in the new San Francisco building laws, as follows:

"When vertical reinforcement is used in columns, such as rods, they shall have full, perfect bearings at each joint, and such joints shall occur only at floors or other points of lateral support, and a tight fitting sleeve shall be provided at all joints of vertical reinforcing rods."

More than this, there is an excellent provision in these same laws, for the transfer of wind stress in such columns:

"In case of buildings in which allowance must be made for wind pressure, the reinforcing rods of concrete shall be connected by threading the rods and by threaded sleeve nuts, or threaded turnbuckles or methods equally effective and satisfactory to the Board of Public Works."

It is not easy to see why these or similar rules should not be applied to other reinforced concrete structures as, for instance, high chimneys or reinforced concrete arch bridges. Any engineer who has had to do with the placing of reinforcing rods in a concrete arch where the present practice is to transfer the tensile stresses in each line of rods by the simple process of extending the ends of the rods a few feet beyond the joints, sometimes bringing thus the projecting ends in close contact with the adjoining rods, will agree that this primitive method should be replaced by efficient, direct joints.

The reason why these last named points were included in this paper is not that they are limitations of reinforced concrete work in themselves, for they are easily altered, but because any improvement in the same implies, necessarily, increased cost. Now in the fierce competitive struggle going on between steel work and wood work on one side and reinforced concrete work, the tendency has been altogether too much in the direction of introducing reinforced concrete on the claim of reduced first cost and at the expense of first-class work.

One of the most striking instances of the tendency to cheapen reinforced concrete work is the fact that reinforced concrete arch bridges in our country are built either with utter disregard of the laws of expansion and contraction under changing temperatures, or by assuming variations of temperature to

suit the requirements of a cheap arch. It has, for instance, been proposed, in all seriousness, to limit in designing reinforced concrete arches, the extremes of temperature to 26 degrees above and below the temperature at which the arch is supposed to be built! To my knowledge, this is the only recorded instance in the history of civil engineering in which, instead of building the works according to the laws of nature, an attempt is made to adjust the laws of nature to the work of man.

Let reinforced concrete work stand on its merits, not on the claim of greater cheapness alone; it can well afford it.

Darwin, somewhere, lays down the law that erroneous opinions are comparatively harmless, because they produce at once in the minds of the listeners a healthy spirit of opposition and criticism, but that it is of the utmost importance that facts are recorded correctly. Well, the facts I have stated are correct; if you think some of the deductions drawn from them are erroneous, the harm, on the quoted high authority, is not very great.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk St., Boston, by June 1, 1907, for publication in a subsequent number of the JOURNAL.]

FIRE PREVENTION APPARATUS.

By John Richards, Member of the Technical Society of the Pacific Coast.

[Presented to be read before the Society, March 1, 1907.]

The writer of this monograph has for twenty years paid for space in a San Francisco building accredited as fire and earthquake proof, in which he kept his stock in trade: references and data relating to engineering and the industrial arts, collected during forty years past in this and other countries. To have this property swept away without a scrap remaining, at an age when memory is too weak to reproduce anything of value, leads one to think of the causes or circumstances that permit such a loss, and a few such thoughts form the subject of this short communication to the Technical Society of the Pacific Coast.

Nature has furnished us with a copious and effectual means of quenching fire, that is, water, and has provided this means in abundance. If, in San Francisco and other cities situated on the shore of the sea, means are not adequate to convey and apply this water, it becomes a reflection on our engineering skill, chargeable, as one must think, to the reasons that prevented the Arkansas pioneer from repairing his roof,—" when it did not rain his house was as dry as any other house."

Here along our water front is lying ready to hand water without end, situated only a few feet below the plane of the most dense and valuable part of the city. The arts have provided us with simple and effectual means of applying this water and impelling it under any pressure and to any distance required, so that the problem of fire prevention becomes narrowed down to the single feature of " conveyance."

To this point of conveyance then is confined the problem of fire extinguishing. It is not a very easy problem, of course; that is, the many methods that may be made use of produce an intricacy of the problem and lead to a wide range of opinions, and this is often the basis of inaction; in fact, is a direct cause of inaction.

This and all similar problems should be approached by generalization, that is, by considering generally the principles that apply, and when these are ascertained, concrete plans of a

logical and conservative nature will appear and will follow to successful consummation.

The conditions are not at all intricate, and resolve themselves into cost or investment, maintenance, flexibility of distribution, celerity, disturbance by earthquakes, area of supply and such constructive precedents as there are to observe.

I will remark briefly upon some of the conditions, first pointing out that this city, or, as I should say, California, pays less attention to precedents than any other part of the world and on the whole has gained by originality and boldness in her engineering; hence is prepared to grapple with the fire problem where departure from custom seems desirable.

Passing over the first two elements of fire extinguishment, original supply and means of impelling water, and speaking of the subject of conveyance, first is the matter of investment. In respect to conduits of any kind it must be stated that the cost of these is governed almost directly by the velocity at which the water is conveyed. It will cost approximately four times as much to convey water in conduits, at the rate of 5 ft. per sec., as it will to convey the same water at 20 ft. per sec.

This, for economy, points to initial propulsion and pressure. Any other system would involve cisterns for storage, a sub-divided and fixed means of impulsion and distribution, and, lacking power of concentration, would amount to ten times the cost of attendance and maintenance and in a certain sense would be inflexible after all, that is, it could not be concentrated on a particular area; moreover is liable to derangement if not extinction by earthquakes.

To these impediments of slow conveyance and sub-divided impulsion may be added the cost of land area in the most expensive parts of the city. Initial impulsion may be performed on the water, saving thereby not only the expense and use of the land, but at the same time the plant, if we may term it so, would become portable, furnishing a ready means of rapid concentration in case of a conflagration.

This, you will say, points to a fire boat or barge. So it does, but with a difference. Such a boat should be a stable barge provided with units of rotative pumping apparatus capable of working up to the required volume and pressure, operating through pipe lines of one to two thousand feet. The engine shaft should extend through the pumps to a simple steam engine and be clutched to a propeller shaft, also to the pumps.

On the main deck of this barge, and level with the pier

floors, there should be carried, in suitable racks, one to two thousand feet of sheet metal or other pipes of 5 to 8 in. bore, made in sections about 50 ft. long, having at the ends plain flanges to be connected with "U" clips driven with hammers; not screw threads or other ingenious connections, but something any one can apply or remove instantly.

Hose I do not consider suitable because of its perishability, uncertain strength and heavy unwieldy nature. Of course initial sections of the conducting pipes could be of flexible nature to accommodate angles and movements of the barge, but even these could be of metallic structure.

Pipes of this kind may be laid in the gutters of the streets by wholly unskilled people at the rate of half a mile in half an hour, and for different distances in proportion. Shields for crossings when streets cannot be barred, and other details of use, would offer no impediments of a serious nature.

A tolerably long and extensive experience in the impulsion and conveyance of water has suggested to me the means here briefly described of dealing with fires within a mile or so of the water front and for shipping. For districts farther from the water, stationary plants of a like nature would be required to attain celerity of action, especially in residential districts, but to save the mass of a city lying on a shore, plain simple fire barges constructed with the features such as named seem most efficient and can be provided at a very moderate expense.

At this point of writing the paper of Mr. Steeb on "Fire Protection Engineering," recently read at Cleveland, Ohio, came to hand, and while the diversified topics can hardly be called "engineering," the paper is one of much value, especially in pointing out the vast economic importance of protection from fire.

The reference to fixed high-pressure main pipes now covers an extensive field now existing, if there is included the dual service of fire and service pressure in the same pipes. This latter scheme is old and has been common for sixty years past without, however, attaining the confidence that its nature suggests.

Many of the larger towns in California have provisions for high pressure in the distribution pipes attained at small expense and expedient in nearly all cases over centralized areas; but there are limitations of various kinds, especially in San Francisco, and other means will have to be provided where fresh water supply is limited and is in the hands of a private company.

Mr. Steeb's idea of special fixed mains is open to the objections already pointed out, and others. It calls for a prohibitive investment and conflicts in the streets with the numerous and increasing structures that must be contended with there. It is too vast a thing for emergency use and its maintenance for salt water would prove a burden calling for serious consideration.

One thing in the paper referred to is worthy of note. Mr. Steeb mentions that in Cleveland the impulsion for the fire service is from boats, or, as stated, "fire tugs," which, as understood, means a hybrid kind of craft adapted for the two functions of towing vessels and pumping water. This is not unusual, is common, indeed, and is a mistake. A boat or barge fitted for impelling water for fire purposes should be constructed for this special function, in which form the cost or investment would be inconsiderable in comparison, and the adaptation complete, and the same structure could carry its own conduits.

In this latter feature lies the main point which I am attempting to present, and of its practicability I have not the least doubt. It is merely an extension of the present fire system existing all over the world, namely, a portable impelling engine and movable hose or water conduits thereupon, but augmented to a volume sufficient to quench any fire that can occur in this or any other city situated on the seashore.

In the adoption of such a system there is not called into use any feature that is not well understood by all competent engineers and mechanics, except the rapid junction of pipes. There is not a detail but can be contracted for under guarantee with firms here in the city and at a tithe of the expense involved in such other schemes as have come under notice.

DISCUSSION.

Mr. Thos. Morrin. — Mr. Richards rightly says that "it is not an easy problem"; but all will not agree with him, as I surely do not, that the manner of securing the water only when it is needed is the best protection.

First, I am convinced that while the salt water may be the best element for extinguishing fires, it is also the most destructive agent possible in its effect on some classes of goods, which would not be totally ruined were they saturated with fresh water. Especially is this true when we consider the filthy condition of the water along the wharves and front of the city, carrying, as it does, not only the sewage and seepage of the most densely populated portion of the city, but also much of the wash and by-

product of the chemical and other manufacturing works that empty large quantities of vicious and corrosive liquids into the bay that tend to make the water more undesirable than the fire in some instances. Of this, however, we need not enter into details; the point is enough for the present, *i. e.*, merely to open up the many opinions that I sincerely hope will be given this subject before something definite is finally adopted.

As to the mechanical equipment and the manner of distribution, I would prefer the reciprocating three-plunger double or single acting pump with cranks set at 120 degrees one from the other, and of sufficient power and material to resist the heaviest work liable to be required, located in some permanent and convenient stationary shelter, adjacent to a fresh water supply, if possible, but the cleanest water available in any case. Several of the stations should be installed and all made tributary and auxiliary to one great system of mains and branches throughout the present fire district, with hydrants and mains of ample capacity and numbers to deliver 2 000 gal. per min. on any side of any single block in the district, at a pressure not less than 25 lb. per sq. in. at the lowest point. At all available points within the fire limits, as well as outside of them, there should be placed reservoirs and storage basins of 30 000 gallons or more where they do not interfere with the sewers and potable water systems, and at the junction of two or more streets, these basins to fill automatically, and to be used at every fire within the district, so that the water may be changed as often as practicable. These reservoirs are to be not more than 1 500 ft. apart in any direction.

The pumps should be driven by an explosive motor, perhaps a producer gas unit, so that it could be started at any time within from thirty to ninety seconds, and to be as far as possible independent of any other system or plant.

In the matter of local or auxiliary mains for distributing the water, should the street mains be destroyed, the pipe ought to be divided into units not to exceed 150 lb. in weight and not more than 20 ft. in length, with light and convenient bends for corners, and sections fitted with valves for attaching hose at least every block apart, or closer.

No attempt should be made to improve our present system unless an actual improvement is the result, and this should be so far above its present best condition and application that the public must be certain of protection against fire under the most extraordinary adversity or accident, and this I am afraid can be summed up in Mr. Richards' remark, "It is a hard problem."

Mr. Franklin Riffle. — Any effort to solve economically and effectively the problem discussed in this paper is deserving of serious consideration, especially when the author has the distinction of being an experienced and a successful engineer in the treatment of kindred problems. In view of San Francisco's recent disaster there can be no difference of opinion concerning the urgent need of an auxiliary system of fire protection for at least a considerable portion of what was formerly known as the business or down-town section of the city. The work of rebuilding this district has actively begun, and unless plans for a system that will admit of rapid and economical construction are adopted, and vigorously executed, we shall soon have a city of new buildings exposed to the same conditions of fire hazard as existed before. As Mr. Richards has pointed out, San Francisco is blessed with a never-failing supply of water, and all that is required to utilize it for quenching fire is to install, operate and maintain a system of pumps and pipes. The engineering features of such a system are comparatively simple, whether we adopt the system of fixed pipes supplied by gravity from a reservoir on Twin Peaks, that of fixed pipes supplied by direct pumping pressure, or that of portable pipes also supplied by direct pumping pressure, as discussed by the author. It is the opinion of the writer that any one of these three systems, if constructed in accordance with the best engineering practice, will furnish an effectual means of preventing conflagrations, although a careful analysis of each would no doubt show a wide difference in cost of installation, operation and maintenance, and probably, also, some difference in efficiency.

Of the three systems mentioned, the first (the reservoir system) is unquestionably the most expensive. Without having seen the plans now in course of preparation by the city administration, or even an estimate based on these plans, the writer does not feel that he is qualified to discuss fully this phase of the question. However, if we take into consideration the cost of the long supply main to the reservoir, the cost of the long main required to convey water from the reservoir to the distributing pipes in the congested district, and, finally, the cost of the reservoir, it would appear that the construction cost of such a system would vastly exceed that of a direct pressure system.

The direct pressure plan apparently combines all of the protective features of the reservoir system, and possesses the important economic feature of eliminating the construction and maintenance costs of the reservoir and long mains, together with

the operating cost of pumping water to an unnecessarily high elevation. For economic reasons, therefore (assuming that the two systems would be equally effective), there appears to be little or no justification for the present action of the municipal authorities in wasting valuable time elaborating plans and details for a system that will probably never be constructed, owing to its excessive cost. The writer predicts that the estimated cost of the reservoir system will be so high that the scheme will be abandoned as impracticable, in which case the direct pressure system will receive the attention it deserves.

Coming now to the portable pipe system proposed by the author, there can be no doubt of its low cost compared with a system of fixed pipes. In addition to this important advantage, it possesses one other of scarcely less importance, *i. e.*, the comparatively short time required to construct it. These two considerations should commend it, provided there is no doubt about its practicability or efficiency. Regarding its practicability, there would appear to be little chance for argument, but there may be a reasonable doubt concerning its efficiency when compared with a system of fixed pipes. The latter (in theory, at least) would be immediately available, while the portable system would always be attended with more or less delay before it could be made effective. The length of time required to take the pipes from their racks, and to distribute and connect them, might be a half hour, an hour, two hours, or longer, depending on circumstances, which no amount of human foresight could absolutely control. This delay might result in the destruction of much valuable property, which would be saved by a system that could be brought into immediate action. On the other hand, it is not improbable that the efficiency of the fire department employees would overcome this objection. It is a question that can be settled by no amount of theorizing. A practical efficiency test might quickly dispose of any and all objections. Some of our public-spirited citizens, who can spare the money, could not serve their city better than to arrange with Mr. Richards to construct an experimental plant in accordance with the general plan outlined in his paper.

There is no doubt in the mind of the writer that if the system under discussion had been in operation at the time of the recent disaster the fire department would have been able to save from destruction a large portion of the down-town section of the city.

Regarding the suggestion that fixed pipes are liable to be

disrupted and rendered useless by an earthquake of unusual intensity, the writer believes that if steel pipes are used, and special attention is given to their foundations, no fears need be entertained on this score. In those sections of the city where the water company's mains were damaged by the earthquake because of unstable foundations, it would be necessary to take exceptional precautions against rupture at the joints, either by preparing stable foundations by piling, or by using some form of flexible joints. It is true that this would add materially to the cost of construction, but in the light of our recent unfortunate experience, the plans for any fire protection system employing fixed pipes must be considered deficient unless adequate provisions are made for safeguarding the joints against rupture by a severe earthquake shock.

The writer heartily endorses the author's statement regarding the advisability of using higher velocities than are usually employed for the conveyance of water through pipes. The practice of adopting low velocities is uneconomical, since it frequently doubles the cost of a pipe line without apparently yielding any benefits that are in the least commensurate with the additional expense involved.

Although convinced of the feasibility of the author's proposed plan for additional fire protection, the writer would not be understood as advocating its adoption to the exclusion of fixed pipes. For reasons suggested above he believes the latter to be more efficient, although he is not prepared to state that the increased efficiency is worth the increased cost. Possibly a combination of fixed and portable pipes would assist to a great extent in disposing of the objections to each as an independent system. The pumping plants (these would be required for any one of the systems mentioned) and the portable pipes could be constructed and made available first, while the necessary fixed pipes could be installed later. Such a system would have the merit of affording additional fire protection at the earliest possible date, besides making it possible to omit many of the fixed mains that would be absolutely necessary in a single system of fixed pipes.

One thing is clear. Some definite plan of action should be decided upon at once and actively carried through to a finish, if the owners and occupants of the new buildings now being constructed and planned are to be given adequate fire protection and relief from burdensome insurance. If the same amount of effective energy could be injected into this project that is fre-

quently met with in private undertakings of similar magnitude, a satisfactory auxiliary fire protection system would be completed almost as speedily as a modern office building. And herein lies the real difficulty. The engineering difficulties to be overcome are small, indeed, when compared with the almost hopeless task of securing the requisite administrative initiative, without which nothing tangible can be accomplished. The people of San Francisco elected the present administration under the mistaken idea that it would be found capable of coping with such problems as this, but up to the present time its achievements have not been of such a nature as to give us the slightest encouragement to believe that the project under discussion will be handled with that intelligence and regard for the best interests of the city that the exigencies of the case demand.

MR. GEO. W. DICKIE. — This short suggestive paper by my friend, Mr. Richards, has interested me very much. Like him I lost the data that represented my life's work, and practically all the material things I had gathered during a busy professional life.

To many thinking men besides Mr. Richards the idea of using the sea water as a means of extinguishing fires has presented itself, and in several cities partial systems have been installed, but nowhere has any attempt been made to lay a pipe line immediately on an alarm of fire within the limits that such a system could reach. Mr. Richards admits that the problem is not an easy one, and I doubt if an 8-in. pipe could be laid at the rate of half a mile in thirty minutes. Such pipe, in 50-ft. lengths, and to stand the pressure required, would weight about 1 000 lb. each length. This would not be very easily handled, although I think automatic locking joints could be designed to be depended upon. There would be no difficulty about the pump barge or the pumps, but the transportation of the pipe and laying of it present the greatest difficulty. To be effective the radius of action would have to be at least one mile. This would be 106 lengths of 50 ft. If these were all ready and loaded on special automobile cars, each carrying 10 lengths, with means of handling them, the load on each would be 5 tons. The barge would carry these cars loaded and ready and with an apron long enough to run them on to any wharf by having proper starting marks.

The laying of the pipe could proceed at ten different points, each section joined by a flexible part. I think by some such device it might be possible to reach a fire in the heart of San Francisco from the bay inside of an hour from the alarm.

In the meantime, of course, the usual methods of fighting a fire at the beginning would be in operation.

It is difficult to foretell what degree of expertness could be reached in pipe laying, and I think that it might be a matter of astonishment to even those best able to judge what regular practice can achieve.

Mr. Richards may be well on the safe side in saying that half a mile of 8-in. pipe could be laid in half an hour. The subject certainly is one well worth a careful study.

[NOTE. Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by June 1, 1907, for publication in a subsequent number of the JOURNAL.]

OBITUARY.

George Henry Evans.

MEMBER OF THE TECHNICAL SOCIETY OF THE PACIFIC COAST.

THE Technical Society of the Pacific Coast has lost one of its old members, one who, although not a frequent visitor, had been a life member for many years.

George Henry Evans died at Berkeley, Cal., on February 4, 1907. He was taken suddenly ill and an operation on the gall bladder resulted fatally. His death has caused widespread regret in San Francisco, where he had a large number of friends. Born in Hull, in England, forty-one years ago, he was a mining engineer in active and successful practice. His specialty was placer mining. He was the inventor of the Evans hydraulic elevator now used in most hydraulic mining where the elevation of gravel is necessary. He was a member of the North of England Institute of Mining and Mechanical Engineers, the American Institute of Mining Engineers, the American Society of Mechanical Engineers, the Technical Society of the Pacific Coast and the Franklin Institute. He was also a member of the Bohemian Club of San Francisco, where he had a wide circle of friends. He leaves a widow, son and daughter. He came to California ten years ago to take charge of the operations on the Golden Feather Channel, at Oroville, succeeding Colonel Frank McLoughlin as manager. This position he held for three years, until he became manager of the Banner Mine, also in Butte County. Subsequently he traveled widely, becoming consulting engineer of various alluvial enterprises in Colorado, California and elsewhere. He was one of the consulting engineers associated with the Risdon Iron Works. As a member of several engineering societies he had a wide acquaintance, among whom his kindly disposition and cultivated manner made him always welcome. The engineering profession has lost a worthy member.

The Society was apprised of the sudden death of Mr. Evans, and the above data were sent through the courtesy of Mr. A. S. Moore to the Secretary.

OTTO VON GELDERN.

OBITUARY.

William Winslow Burnham.

MEMBER OF THE SANITARY SECTION OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

WILLIAM WINSLOW BURNHAM was born in Biddeford, Me., August 24, 1875, the son of Francis M. and Abby M. Burnham. He received his early education in the public schools at Biddeford, but owing to his father's death when he was twelve years old he was obliged to leave school, and was employed in a stationery store. While carrying on this work he prepared himself for Bowdoin College, but as his tastes were more along engineering lines he entered the Massachusetts Institute of Technology in 1899, graduating from the sanitary engineering course in 1903.

Immediately after graduation he took a position as assistant in the engineering department of the Massachusetts State Board of Health. In June, 1904, he accepted a position with the United States Geological Survey as hydrographic aid, which position he held until February, 1905. His work here was the determination of the depth and character of the ground water in the Nevada desert known as the "Carson Sink" and an investigation of the character of the surface and ground waters of Georgia.

In February, 1905, he entered the employ of the Hugh MacRae Company, of Wilmington, N. C., which position he held until his death. His work with this firm was in connection with the irrigation and drainage of large tracts of land in North Carolina.

Mr. Burnham married Miss Ella M. Cate, of Malden, Mass., March 6, 1906. He was taken ill with typhoid fever June 23 and died August 11, 1906. He was a member of the Sanitary Section of the Boston Society of Civil Engineers and of the New England Water Works Association.

ELBERT E. LOCHRIDGE.
WILLIAM S. JOHNSON.

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GAS ENGINEERING.

BY W. A. BAEHR, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read before the Club, March 20, 1907.]

Mr. President and Gentlemen,—When I was first requested to read a paper before the Engineers' Club of St. Louis it was with the understanding that I might select any subject provided it was connected or related to the gas business. This appealed to me as an opportunity to open a discussion on some particularly interesting branch of our work, but on second thought it appeared to be more desirable to cover the field in a general way and for various reasons. Among these might be mentioned the idea of securing greater interest among the engineering profession at large than would be obtained by a purely technical paper, and further of adding my mite towards the better understanding of the general features of the gas business by people not connected with it.

It is difficult at present to assign a good reason why the gas business should be considered mysterious in any way since in all companies with whom I have been associated it has been the invariable custom to welcome visitors to the works and shops, and to carefully explain all the steps in the processes of manufacture and distribution, as it is believed that a broad, liberal and open policy is superior and more conducive to the good will of the public than the old idea of concealment.

GAS ENGINEERING.

It is rather difficult to define gas engineering. During the reading of this paper it will develop that a gas engineer has

need of civil, mechanical, electrical, and chemical knowledge, and I will therefore leave the definition of this profession to crystallize in your minds during its progress.

Division of Subject.

It would be wholly beyond the scope of a paper such as this to endeavor to include even a general consideration of the economic geology and chemical technology of the materials for gas manufacture. I will therefore omit these subjects entirely, and will pass on to the two great divisions of the gas business, viz., natural gas and artificial gas.

Natural Gas.

This again is a subject which I will not endeavor to cover except in a skeleton outline. Since natural gas is found in nature, man takes it as he finds it, and the methods in use for its distribution differ from those I will describe later only in the point that usually much higher pressures are employed in transmitting it from the fields to the centers of consumption than are in use for transmitting artificial gas. The question of the origin of natural gas fields, collection, wells and well machinery, methods of controlling wells, their location, arrangement and operation, transmission, questions of pumping plants, etc., form ample material for a separate paper. Natural gas is an important economic factor among the industries of our country, but suffice it to say that it is largely composed of methane, or CH_4, and has a high thermal value, usually from 900 to 1 000 B.t.u. per cubic foot when burned in air. It is usually gathered from the various gas wells in a district by means of comparatively small screw pipes, which terminate in a common large header, which leads to the centers of consumption. If the line is not too long, and the pressure is sufficient, the transmission system is a simple pipe line. If other conditions exist it may be necessary to install one or more compressing stations along the line. At the points of consumption the line pressure is reduced through governors into a secondary low-pressure system, or by individual governors directly to each consumer.

Artificial Gas.

We naturally divide gas engineering into two parts: Manufacture and distribution. The former embraces all the steps from the crude to the finished product, while the latter takes the gas from the outlet of the works and leads it through various paths and apparatus to the consumer's burner.

Manufacture.

Under this heading, and stated in the order of their importance, we can group the production of the following kinds of artificial gases:

1. Coal gas.
2. Water gas.
3. By-product coke oven gas, such ovens being distinguished from the bee-hive type.
4. Producer gas.
5. Oil and Pintsch gas, — Lowe oil gas.
6. Blast-furnace gas.
7. Acetylene.
8. Gasoline air gas.
9. Miscellaneous, such as resin gas, wood gas, hydrogen-methane gas, garbage gas, CO_2 gas, etc.

Taking these up in order we will first consider the manufacture of

Coal Gas.

This art is over a century old. William Murdoch, in England, between the years 1792 and 1798, was engaged in experimenting with different coals and in devising apparatus for their distillation. In 1797–8 lighting by coal gas became an accomplished fact, for Murdoch by means of his experimental plant first lighted up his dwelling house, and a short time later a considerably larger building at Birmingham.

From these first attempts, coal gas manufacture has successively progressed up to the present time.

The coal used for gas-making purposes is mostly of the caking bituminous variety. In England and on the continent some cannel coal is used, and non-caking or even lignite coal can be made to yield gas.

These latter two varieties do not give the requisite quantity or quality of gas, nor do they yield any valuable by-products except some tar and ammonia. It has been found by repeated tests that it is best to use lump coal in preference to mine run or slack on account of increased gas yield and better resulting coke.

For the successful carrying on of coal-gas manufacture, the fact that the gas works must run day and night and all the year round makes it necessary to have a large coal stock on hand all the time. Furthermore, plants which receive their major portion of coal by water, such being usually the cheaper method of transportation, are limited to a certain portion of the year during

which the water transportation facilities are available. Thus a large stock of coal is bound to accumulate, and I can best illustrate this by stating the storage capacity of a few prominent coal-gas works.

	Population.	Coal Storage Capacity.
Denver (all-rail delivery)	150 000	10 000 tons
Milwaukee	300 000	125 000 ,,
St. Louis (old works)	700 000	150 000 ,,
St. Louis (new works)		probably 500 000 ,,

At $3.00 per ton you can readily see the immense amount of money tied up in coal stock at certain times of the year.

In modern works the coal is handled by the most approved machinery, and in some plants hand labor is practically eliminated.

The distillation of coal is now carried on in clay retorts, usually of a horizontal "D" section. Formerly cast-iron retorts were used, but these would not stand the high heats necessary to drive all the gas out of the coal.

The average size of the horizontal retort in use to-day is probably 16 in. by 26 in. in cross section by about 9 ft. long inside. Such a retort will distill 2 000 lb. of coal per day in six charges, thus taking 4 hr. to burn off one charge. In very recent installations single retorts take as high as 800 lb. of coal in one charge, and the figure is constantly growing.

In most works the retorts are open only at one end, but they are also made with both ends open and are then called "through retorts." These present an important advantage, inasmuch as the coke can be pushed out of them by a comparatively simple discharging machine, which at the same time is readily arranged to also act as a charging machine. In those plants where the retorts are open at one end only, the charging and discharging machinery become more complex.

It is an open question to-day among prominent gas engineers as to whether machine-operated horizontal, vertical or inclined retorts are best. The new Milwaukee gas works is designed with horizontal retorts operated entirely by machinery, and Mr. Brown, engineer of the Milwaukee Gas Light Company, states they figured a saving of $30 000 per year over inclines. It is undeniably true, however, that inclines are used largely abroad, and some new installations are being erected in this country. Retorts for inclined benches are sometimes as much as 20 ft. long, and carbonize a great deal of coal per day. They are usually operated entirely by machinery, and the usual inclination is from 32 degrees to 33 degrees from the horizontal.

Right here it is well to note that the present day is witnessing the evolution of the so-called vertical retort setting. In these schemes the fundamental idea is to use a vertical retort, drop the coal in at the top and extract the coke from the bottom either by continuous or intermittent operations. These settings are being developed extensively abroad, the most notable being the Woodall-Duckham and Settle-Padfield systems in England, and Dr. Bueb's system in Dessau, Germany. It is probably safe to say that the *idea* of the vertical is good, and these systems give promise of good results, but it is equally safe to take the position that they are still in a crude state, and that some years will probably elapse before we shall witness a completely developed system of this type which will be as satisfactory and sure in operation as the present-day horizontals operated by machinery.

The number of retorts per bench varies from one to ten or more. In settings of two retorts per bench the arrangement is either one alongside the other, or one over the other. Where there are three, usually there is a lower tier of two retorts with one over them.

With four retorts per bench the usual design is to place them in two vertical rows of two each. With five, the arrangement is similar to four, except there being a fifth retort between the two vertical rows of twos.

We may well call a bench of sixes, or six retorts per bench, the most common and widespread arrangement. Here the retorts are arranged in two vertical rows of threes, and this bench has long been a favorite one among gas men on account of its ease of regulation and simplicity of construction.

Formerly benches of eight were built with two outside vertical rows of three retorts each, and one vertical row of twos in the center. This gave rise to a very wide retaining arch, and in order to obtain the advantages of the style of construction and of operation of the sixes, foreign engineers designed a type known as vertical eights. In this design there are two vertical rows of four retorts each, and you can readily see that the retaining arch is narrowed to practically the same width as for a bench of sixes.

The first objection to these vertical eights was that the upper rows of retorts were so high above the operating floor that they could not be charged by hand. Later improvements in drawing and charging machines have made mechanical operations so certain and cheap that the objection as to height disappears.

Benches of nines are built with three vertical rows of three retorts each, and benches of tens with two vertical rows of fives. The types can be extended almost indefinitely.

Leaving the upper portions of the benches we will now consider the lower or fire-containing part. Here is the really interesting portion of bench work, and we can divide the various types into the following general classes, viz., isolated generators, and those having one generator or furnace for each bench.

By an isolated generator we mean a gas producer set in a place by itself, away from the stack of benches, and generating a producer gas which is conducted to the benches and burned around the retorts. The success of this type of construction is dependent somewhat upon the nearness of the producer to the benches, as the gas must not be allowed to cool during its passage. There is an important advantage in isolated generators, inasmuch as one such producer can serve several benches, and thus by means of dampers the heat in each bench can be closely regulated.

Isolated generators are used somewhat abroad, but have made no headway in this country. I believe there is a great possibility of their being further developed, and especially so as they offer such excellent facilities for recuperation being carried to its limit, even if iron recuperators are necessary, clay being the style now used.

In the other type, where each bench has its own furnace or generator, the division of design is very pronounced, and is based on fundamental principles of thermo-chemistry. We divide such benches into the following kinds:

1. Direct-fired benches.
2. Half-depth recuperative benches.
3. Full-depth recuperative benches.

A direct-fired bench is one in which the air for combustion is drawn directly under the fire, and in which the carbon burns directly to CO_2, according to the equation, $C + O_2 = CO_2$.

The retorts are thus heated like an ordinary steam boiler by the passage of the hot products of combustion around them and by the heat radiated from the fire.

Each pound of carbon in burning to CO_2 thus produces 14 544 B.t.u.

Theoretically, 11.54 lb. of air are required to burn one pound of carbon to CO_2, assuming that air consists of 23 parts by weight of oxygen, and 77 parts by weight of nitrogen. Theoretically, then, the flame temperature of C burning to CO_2, assuming constant specific heats for the gases at all temperatures for ease of calculation, is as follows:

$$\frac{14\,544}{\begin{array}{c}3.66 \times 0.2164 + 8.88 \times 0.244\\(CO_2 \times \text{sp.ht.} + N \times \text{sp.ht.})\end{array}}$$

$$= \frac{14\,544}{0.792 + 2.167}$$

$$= \frac{14\,544}{2.959} = 4915 \text{ degrees fahr.}$$

I wish to explain right here that I am satisfied that the specific heat of gases increases with increase in temperature, but for the purposes of this lecture it would only result in confusion were I to attempt to use such calculations, and I therefore use constant values so your minds may be kept clearer concerning the relations of the various parts of the art.

As a matter of interest I here insert a table on the specific heats at various temperatures of H_2O, CO_2, CO, N_2, O_2 and H_2, as determined by Dr. H. B. Harrop, who based this table on all the data he could gather in this country and Europe. It shows how erroneous our ordinary heat calculations are, even though this table be somewhat modified by subsequent investigators. At any rate they are the best data available on this subject of which I have knowledge, and having made some efforts personally to gather similar information, I am glad to accord thanks to Dr. Harrop for his work.

Fahrenheit.	H_2O.	CO_2.	CO & N_2.	O_2.	H_2
32		0.182	0.238	0.208	3.36
212	0.360	0.201	0.242	0.212	3.42
250	0.408	0.204	0.243	0.213	3.435
300	0.445	0.209	0.244	0.214	3.452
350	0.480	0.214	0.245	0.215	3.469
400	0.504	0.218	0.246	0.216	3.486
450	0.522	0.223	0.247	0.217	3.503
500	0.536	0.228	0.249	0.218	3.520
600	0.563	0.237	0.252	0.220	3.554
700	0.587	0.246	0.255	0.222	3.588
800	0.609	0.255	0.258	0.224	3.622
900	0.625	0.263	0.260	0.226	3.656
1000	0.641	0.270	0.262	0.228	3.690
1100	0.655	0.277	0.264	0.230	3.724
1200	0.670	0.283	0.267	0.232	3.758
1300	0.685	0.289	0.269	0.234	3.792
1400	0.699	0.295	0.272	0.236	3.826
1500	0.712	0.300	0.275	0.238	3.860
1600	0.723	0.306	0.278	0.240	3.894
1700	0.734	0.312	0.280	0.242	3.928

Fahrenheit.	H_2O.	CO_2.	CO & N_2.	O_2.	H_2.
1800	0.745	0.317	0.282	0.244	3.962
1900	0.758	0.322	0.284	0.246	3.996
2000	0.769	0.327	0.286	0.248	4.030
2100	0.778	0.332	0.288	0.250	4.064
2200	0.787	0.337	0.290	0.252	4.098
2300	0.794	0.341	0.293	0.254	4.132
2400	0.802	0.345	0.296	0.256	4.166
2500	0.809	0.349	0.299	0.258	4.200
2600	0.817	0.353	0.301	0.260	4.234
2700	0.823	0.357	0.303	0.262	4.268
2800	0.829	0.361	0.305	0.264	4.302
2900	0.835	0.365	0.308	0.266	4.336
3000	0.838	0.368	0.310	0.268	4.370
3100	0.841	0.371	0.313	0.270	4.404
3200	0.845	0.374	0.316	0.272	4.438
3300	0.849	0.377	0.319	0.274	4.472
3400	0.854	0.380	0.321	0.276	4.506
3500	0.859	0.383	0.323	0.278	4.540

The above table gives the mean specific heats, at constant pressure, in B.t.u. per lb. of gas as extracted from discussion by Dr. Harrop in *Journal of Gas Lighting*, March 20 and 27, 1906.

In this paper, however, I will use the following heats of combustion:

C to CO_2 = 14 544 B.t.u.
C to CO = 4 400 B.t.u.
CO to CO_2 = 4 348 B.t.u.

Also the following specific heats:

CO_2	0.2164
N	0.244
Air	0.2379
H_2O vapor	0.48

Now the losses which occur in a direct-fired bench are due to several causes, as follows:

1. To over ventilation of fires.
2. To loss of heat in flue gases.
3. To other losses by clinkering, radiation, opening of doors, etc., all of which I will call the X losses.

Concerning the first class of losses, it is well known that in practical direct firing it is impossible to get along without using considerably more than 11.54 pounds of air per pound of carbon. Therefore, the flame temperature is reduced by just the proportion of excess oxygen and nitrogen heated from atmospheric temperature to the temperature of the escaping waste gases.

The second class of losses, or the sensible heat carried away by the flue gases, is due to the fact that in direct bench firing there is no way to keep the stack temperature below about 1 500 degrees fahr., thus wasting all the sensible heat of these gases from a temperature of half the above up. I am glad to say that direct-fixed benches are becoming rare.

Before passing to the second great class of benches it is necessary that you fully comprehend the difference between the terms recuperative and regenerative.

A recuperative bench is one in which both the primary and secondary air, or the secondary air only, are preheated by passing through a flue, or set of flues, without reversal in direction, and continuously the transfer of heat being accompanied *through* the walls of the flues.

Now a regenerative bench would have its primary and secondary air preheated by passing intermittently through a set of flues which are also intermittently heated by the passage of the waste gases. The point is that the transfer of heat is not accomplished *through* the walls of the flues, but by contact on the same surfaces as were touched by the waste gases.

In the ordinary coal gas construction regenerative benches are not used at all, but in some forms of by-product coke ovens they are used. Bearing in mind then that recuperative benches are those used, we can easily define half-depth and full-depth benches as follows:

A half-depth recuperative bench is one in which the secondary air only is preheated, whereas in a full-depth bench both the primary and secondary air are preheated.

With these definitions I can now proceed to explain modern gaseous firing. This consists of a deep furnace below the bench in which the carbon is first converted into CO_2 in the lower layers of the fuel bed, and this CO_2 on passing up through the incandescent carbon decomposes to CO. The air which is admitted below the fire is called primary air.

The CO from the fuel bed passes up through the furnace arch opening and meets the secondary air, which has been preheated by passing in through the recuperators, and surrounding the retorts is the combustion chamber, and here the CO burns to CO_2.

Now, when the water is admitted below the fire in the ash pan it vaporizes, and in passing through the fire decomposes into H and O. The oxygen first unites with C to form CO_2 and this in turn decomposes to CO. Thus the gas issuing from the fur-

nace contains N, CO and H. The H in the combustion chamber immediately burns to H_2O vapor again. The water in the ash pan is used to aid in preventing clinkering and I will now explain a new rational method of clinker prevention which I think will appeal to all.

Clinkers form because when a fire burns too rapidly a high local temperature is produced, and the ash fuses. Now in gaseous firing we burn the carbon to CO_2 in the bottom of the fuel bed and form clinkers. By passing H_2O vapor up with the primary air as soon as this vapor comes in contact with the hot spots it is decomposed. The decomposition is an endothermic reaction; that is, heat is absorbed and thus clinkers prevented.

Again in gaseous firing we aim to produce CO in the generator and do it by forming CO_2 in the bottom of the fire. Now, when CO_2 decomposes to CO, the reaction is also endothermic; consequently the point is, Why can we not introduce CO_2 below the fire; in other words, get just what we want there, and then, by having the aforesaid endothermic reaction taking place, prevent the ash from fusing? This is exactly what we can do, and our old friend Siemens, of regenerative furnace fame, did the same thing. He derived his CO_2 from the waste gases, but he introduced it by means of a steam jet and defeated the very object he was after. He put his fire out. However, this CO_2 with the waste gases can be introduced by means of air jets, blowers or other devices.

You see we do not wish to use water under the fire because the high specific heat of H_2O vapor causes too many B.t.u. to be carried out of the chimney with the waste gases. I regard this use of CO_2 of the waste gases as one of the most important advances of gaseous firing of modern times, as by preventing clinkers we can run gas producers at extremely high tension, that is, under heavy blast pressure.

Before leaving the subject of recuperative benches I will state that gaseous firing has several great advantages over direct firing, among which are the following:

1. The excess of air per pound of carbon is reduced to a minimum.

2. The recuperation enables us to recover a large part of the sensible heat of the waste gases.

3. Regulation is rendered easy.

4. Wear on benches is greatly reduced.

5. There is a great saving in operating expense.

To show the comparative theoretical thermal efficiency of a half-depth and a full-depth bench I will give the following calculation. The temperatures in different portions of a bench were determined by means of a Le Chatelier pyrometer and are as follows:

Temperature	just above fire	2000	degrees fahr.
,,	in combustion chamber	2500	,,
,,	waste gases, top of recuperator . . .	1500	,,
,,	waste gases, bottom of recuperator . .	750	,,

For full-depth bench:

Heat Produced.

1 lb. of C with 2.66 lb. O and 8.88 lb. N. to 3.66 lb. CO_2 and 8.88 lb. N . . . . 14 544 B.t.u.

Losses.

3.66 lb. CO_2 from 60 degrees to 2500 degrees fahr. = $3.66 \times 0.2164 \times 2440$ . . . . 1 932 B.t.u.

8.88 lb. N from 60 degrees to 2500 degrees fahr. = $8.88 \times 0.244 \times 2440$ . . . . 5 287 B.t.u.

Gross loss . 7 219 B.t.u.

Recovered by absorption in secondary air, which would be,

$$5.77 \times 0.2379 \times 2440 = 3\,349 \text{ B.t.u.}$$

The flue gases would have a specific heat of 0.236 and the temperature of the escaping gases at the bottom of the flues where secondary air is admitted would be,

$$2500 \text{ (degrees)} - \frac{5.77 \times 0.2379 \times 2440}{12.54 \times 0.236} = 2500 \text{ degrees} - \frac{3\,349}{2.959}$$

$$= 2500 \text{ degrees} - 1132 \text{ degrees} = 1368 \text{ degrees fahr.}$$

Then the heat recovered by absorption in the primary air would be

$$5.77 \times 0.2379 \times (1\,368 - 60) = 1\,795 \text{ B.t.u.}$$

The final temperature of the escaping gases would be,

$$1368 \text{ degrees} - \frac{5.77 \times 0.2379 \times (1\,368 - 60)}{12.54 \times 0.236}$$

$$= 1368 \text{ degrees} - \frac{1795}{2.959} = 1368 \text{ degrees} - 606 \text{ degrees} = 762 \text{ deg. fahr.}$$

Then the net loss of heat = 7 219 — (3 349 — 1 795) = 2 075 B.t.u.

Therefore the theoretical thermal efficiency of a full-depth bench, not allowing for radiation, opening of doors, etc., would be

$$(14\ 544 - 2\ 075) \div 14\ 544 = 85.73 \text{ per cent.}$$

For a half-depth bench the heat produced and the gross losses are the same as for a full-depth bench, as is also the heat recovered by absorption in the secondary air. But there would be no recovery in the primary air, and therefore the net loss for a half-depth bench would be,

$$7\ 219 - 3\ 349 = 3\ 870 \text{ B.t.u.}$$

The theoretical thermal efficiency, with previously mentioned omissions, for a half-depth bench would then be

$$(14\ 544 - 3\ 870) \div 14\ 544 = 73.39 \text{ per cent.}$$

In operating any kind of a furnace I will add that there is only one way to do so correctly, and that is by flue gas analysis. We usually determine the percentage by weight of CO_2, O, CO and N. Knowing that air consists of very nearly 23 parts of O and 77 parts of N by weight, we know that this relation of O and N must be maintained in all the flue gases.

Before leaving the subject of coal gas manufacture I will add that a typical composition of coal gas is as below in per cent. by volume.

CO_2	1.5
CO	7.0
O	0.5
Illuminants	7.0
CH_4	34.0
H	46.0
N	4.0
	100.0

We will next consider the manufacture of

Water Gas.

Water gas was experimented with and virtually invented by Tessie du Motay, a Frenchman, in about 1865, but Professor Lowe in America practically perfected the apparatus that bears his name about the same time.

I can only take a few moments to explain the operation of a modern Lowe water gas set. There have been many forms of water gas apparatus, but that named above is the one most widely used now. Such a set consists of,

First. A generator, or vessel built of an iron shell, with a firebrick lining, and containing a deep bed of incandescent fuel.

Second. A carburetter, or vessel consisting of an iron shell, lined with firebrick, and filled with a checker work of firebrick. This vessel has an open chamber near the top into which the oil is sprayed.

Third. A superheater, or vessel built similar to the carburetor, but without the oil chamber.

To explain the operation of such a set we will first assume it cold, but with a coke or anthracite fire started in the generator. By means of a fan blower a blast is turned under this fire, and the carbon in the lower portion burns directly to CO_2. This on passing up through the fuel bed is wholly or partly decomposed into CO, the amount depending largely upon the velocity of the blast. In the Delwick process this blast velocity is high and the fuel bed is shallow, so that the carbon is kept in the form of CO_2.

When the producer gas (for such it is) reaches the top of the generator above the fire it consists of principally N, CO and some CO_2. By means of a large firebrick-lined connection this mixture is conducted to the top of the carburetor. Here an additional blast opening introduces fresh air, and a portion of the CO in the producer gas burns to CO_2 in the carburetor. The resulting mixture passes out of the carburetor and into the bottom of the superheater, where still another blast admits enough air to burn the remaining CO to CO_2. The final waste gases then pass out of the stack valve at the top of the superheater and escape into the atmosphere, or pass through a Green economizer or other contrivance to heat feed water, or for other purposes. The process of blasting, or blowing, is continued until the entire fuel bed in the generator is at a white heat, the carburetor being then full of a checkerwork of firebrick at a glowing red heat, and the superheater at a slightly lower color than the carburetor. The set is now ready to make gas.

The blast is first shut off all the vessels, and the stack valve on top of the superheater is closed. Then live steam is turned into the generator below the fire. The resulting reactions are very instructive. The H_2O is first decomposed by the incandescent heat to H and O. This reaction is endothermic, that is, heat is absorbed in doing that work. The hydrogen passes up through the fire unchanged.

The oxygen on the other hand immediately combines with carbon to form CO_2, and every pound of carbon thus burning

delivers 14 544 B.t.u., the reaction being exothermic. The CO_2, however, on passing upwards through the fire, decomposes into CO with an endothermic reaction, and this CO appears on top of the fire mechanically mixed with the hydrogen. This mixture is the so-called blue gas, or uncarbureted water gas, and is merely one form of producer gas, having a calorific value of about 350 B.t.u. per cubic foot.

You will note that the reactions in the generator are mostly endothermic, and in fact the fire is cooled very rapidly under the admission of the steam, a run generally being from 7 to 10 min., at the end of which time it is necessary to blast up again.

Coming back to the blue gas, so called because it burns with a blue flame in the air, we find it passing into the top of the carburetor. Here it meets with a spray of oil. This is sometimes the crude oil, but more often a gas distillate, which is obtained from crude oil after distilling off the gasolines and kerosenes, and before the heavier lubricating oils appear. The fraction coming off between these two extremes is neither fit for illuminating nor lubricating purposes, but is simply a fuel oil, excellent for boiler use, but I believe is now mostly directed towards making gas.

This oil, on coming into the top chamber of the carburetor, vaporizes under the intense heat, and mixing with the blue gas starts down through the carburetor. The lower portion of the carburetor and the entire superheater are merely heated checker work for the purpose of "fixing" the gas. By the term "fixing" we mean to render permanent under ordinary conditions. It has been found that oil or coal gas, if not subjected to sufficient heat, on coming to atmospheric temperature partially condenses into liquid hydrocarbons, and it is to render these hydrocarbons permanently gaseous that "fixing" chambers are employed. This of course involves a change of the hydrocarbons into different series and components of series.

The practical result of adding the oil is to make carbureted water gas, which is luminous and of higher calorific value than the blue gas. The average heat value is from 600 to 650 B.t.u. per cubic foot, and it can be made up to 35 or even 40 c-p. although that is beyond the customary limit, which is about 23 to 25 candles.

When the set has been making gas for a certain number of minutes, it becomes too cool for economical operation. The oil is then shut off, next the steam and then the stack valve is opened. Thereupon the blast is turned under the fire and the whole operation is begun over again.

On account of the steam striking the under side of the fire and cooling it too rapidly it is now customary to make a so-called "down run" every second or third time. This simply means that the steam passes down through the fire, the connections on the machines being arranged so as to permit this. As often as the fire requires it, fresh coke or coal is admitted into the generator, the ashes and clinkers being taken out at the bottom.

In places where anthracite is reasonably cheap it is used, but probably the large majority of plants use oven or gas coke. Bituminous coal can be mixed with the coke, or even a small proportion of lignite, but the latter does not work well.

In order to give you an idea of the capacity of a water gas set, I will say that an 8 ft. 6 in. set, with a grate area of 30 sq. ft., has a capacity of, roughly, 25 000 cu. ft. of gas per square foot of grate. An 11-ft. set in St. Louis operating on gas coke can produce, roughly, 35 000 cu. ft. of gas per square foot of grate area, or with anthracite coal as high as 42 000 cu. ft., all per day of 24 hr.

As I wish to take up the treatment of gases as a separate subject a little later on, we will now pass to the manufacture of

By-Product Coke Oven Gas.

By-product coke ovens are an outgrowth of a desire to secure an economical arrangement of apparatus to utilize the gas, tar, ammonia and cyanogen produced while manufacturing coke, at the same time not reducing the quality of the coke produced from that obtained from beehive ovens. They were first in evidence in steel plants, and the industry is represented in the United States by the United Coke and Gas Company, and the Semet-Solvay Company.

By-product coke ovens not only affect the gas industry by producing gas, but they contribute large quantities of coke, tar and ammonia to the market. These ovens are nothing more or less than sets of large built-up retorts. Approximately the first 40 per cent. of the coal gas given off is sold as illuminating gas, as it is the richer portion, the remainder of about 60 per cent. being used to heat the retorts, and this 60 per cent. is of a low photometrical and calorific value. The operation of such ovens is not very different from a large modern gas plant, except the much larger scale upon which it is carried out. The very magnitude renders mechanical devices for handling everything absolutely necessary.

I do not wish to dwell long upon any of the gas manufacturing processes except coal and water gas, and will therefore con-

fine my description by illustrating the size of a by-product coke oven plant with whose design I am associated.

This plant is to consist of 400 Semet-Solvay or Otto-Hoffman ovens, erected in eight stacks of 50 retorts, or ovens, each. It will use, per day of 24 hr., 3 000 tons of coal. The products will be about

1 700 tons of coke per day.
40 000 gal. of coal tar per day.
15 000 lb. of anhydrous ammonia or
60 000 lb. of ammonium sulphate per day.

I will leave it to you to construct, in your minds, the machinery necessary to perform all this.

In connection with the subject of by-product coke ovens I take this opportunity of emphasizing the advantages of these plants as an aid in the great problem of smoke prevention. As you know, there has been considerable agitation in St. Louis for the abatement of the smoke nuisance. The increase in the use of gas and of coke instead of soft coal wherever a solid fuel is required, is certainly a step in the right direction.

The coke from a by-product coke plant would be available for the small and carelessly operated boiler plants which are the chief sinners at present, and also for domestic heating furnaces, and for other uses to which gas has not yet been applied. Coke, being a smokeless fuel, and available at moderate cost, would offer the means for more easily enforcing the legal restraints of smoke production.

Producer Gas.

This gas is usually made by one or both processes already explained under coal gas and water gas manufacture. It sometimes consists of CO and N produced by air being blown through a bed of incandescent fuel, and is then possessed of a heat value of about 140 B. t. u. per cubic foot. If in addition to the blasting process we add steam under the fire, the resultant gas will contain H, CO and N, as previously explained. Of course there are always some impurities as CO_2, H_2S, etc., associated, but I am naming only the principal constituents.

Producer gas is coming into prominence of late owing to great advances in the design of gas engines, and those interested can secure much pleasure and benefit from studying up such processes as the Mond, Dowson, Duff, Wood, Morgan, etc.

Oil and Pintsch Gas.

Since Pintsch gas is a pure oil gas I will describe it. Such a gas is usually used where a high candle-power is necessary, and

in the Pintsch gas system it must stand comparatively high compression without liquefaction of too large a part of it. The average coal gas made is probably 16 c-p. in this country; but in England and Europe the poor grades of coal obtainable will produce gas of only from 8 to 14 candles. It was formerly the practice to enrich coal gas by the addition of oil gas, but the water gas process is doing away with that.

In the Pintsch system we have probably the largest application of pure oil gas there is in vogue. The process is to distill and gasify the oil in iron or clay retorts very much as coal gas is produced, but with this difference, — the oil is run into the retorts constantly in a small stream, and they are opened only for cleaning out and decarbonizing.

Under coal gas manufacture I should have added that retorts periodically carbon up, that is, the heat of the retorts breaks up some of the hydrocarbons formed during distillation and carbon deposits on the sides and bottom of them. This carbon deposit is very dense and hard, and is removed by burning it off the walls of the retorts. You have all seen this substance, for it is used largely to manufacture electric arc light carbon.

Now in oil gas the same thing occurs, and were it not for carbon and tar deposits an oil retort might be used indefinitely. Pintsch gas is of about 60 c-p., and after purification is compressed to from 10 to 20 atmospheres and is thus stored in strong tanks under railroad cars, where it is used for lighting. Our Pintsch plant in St. Louis has 400 000 cu. ft. daily capacity, and can gas 1 200 to 1 400 cars daily. This plant is one of the largest of its kind in the world, and was practically taxed to its capacity during the World's Fair.

Lowe Oil Gas.

There is one other noteworthy application of oil for gas-making purposes, and that is the Lowe oil process. This consists of an apparatus similar to a water-gas set. To heat it, oil is burned with air directly in the generator and superheater. These vessels are filled with a checkerwork of firebrick, which heats up to a bright red under the hot oil fire. When the heat is up, the air is cut off and the oil is admitted alone. This vaporizes and gasifies the oil, which gas is afterwards mixed with air to reduce the candle-power to a reasonable commercial basis, say 20 candles.

You can readily see that such a process is only applicable where oil is plenty and cheap. Both it and the Pintsch system require about 15 gal. of oil per thousand cubic feet of gas

made. If oil were 4 or 5 cents per gallon, the common Eastern price, the Lowe gas would thus cost 60 cents per thousand for oil alone. In fact the Lowe oil gas process is used only in or about California, where immense deposits of oil are found, and where it is worth possibly 1 or 2 cents per gallon.

Blast-Furnace Gas.

This subject is not really in the realm of gas manufacture and I will only touch upon it. It is a very low calorific gas, of only about 90 B.t.u. per cubic foot, but is being largely used to drive gas engines, some engineering experts being of the opinion that it is the best available gas for such use on account of its readily withstanding high compression. This brings us to a short consideration of the final classes of gas I will touch upon, viz.:

Acetylene, Gasoline Air Gas and Miscellaneous Gases.

Acetylene, or C_2H_2, is produced by the action of water on calcium carbide. It is a very heavy gas, of high candle-power, and its flame is said to most nearly resemble sunlight in its spectrum, that is, more than any other artificial light. Even though such water-power developments as Niagara and the Sault have rendered the production of calcium carbide reasonably cheap, acetylene is still too dear for general use. For lighting country residences, etc., it finds a limited application, and can be adapted to fuel use if desired.

Wood gas can be made by distilling wood either in horizontal or vertical retorts. A fair grade of coke is produced therefrom, and this process is applied in France and other foreign countries where coal is scarce. This, and garbage gas made by distilling garbage, with many other minor processes, finds a limited application.

I will now pass to the head of

Purification.

Coal Gas. In this gas we extract first the tar, then the ammonia and finally sulphur. In some more modern works cyanogen is also removed.

The tar is largely taken out in the hydraulic main which is situated on top of the stack of retorts. Here the gas bubbles through a seal of tar and weak ammoniacal liquor. The gas next passes to the exhauster, which is usually of the positive rotary blower type and is the heart of the works, driving the gas forward through all vessels and finally into the holder.

Then the gas passes through various mechanical tar extractors and finally washers or scrubbers, through which water is pumped and where the last traces of tar and ammonia are removed.

Rotary scrubbers are usually employed to remove the cyanogen in the gas in the form of ferrocyanide of potash, sodium or ammonia.

The sulphur is the most difficult impurity to remove. In this country we employ mostly iron oxide mixed with shavings. The H_2S in the gas combines with the iron oxide to form iron sulphide. When all the oxide has been "fouled," or is in the form of iron sulphide, the material is taken out of the purifying boxes and exposed to the air. The oxygen of the air causes the iron sulphide to return to the form of iron oxide, leaving the sulphur in the free state among the material. This can then be used over again, and the process repeated until there is approximately 50 per cent. by weight of free sulphur in the mass, when it becomes too sluggish to act.

In England, lime, or rather the hydrated form of quicklime, CaO, H_2O, is used. This is done because lime removes CS_2 as well as H_2S. The process, however, is too expensive.

After purification the gas is ready for commercial use.

Water gas is treated only for tar and sulphur; coke oven gas for the same products as coal gas.

Producer and blast-furnace gas is treated for tar, ammonia and cyanogen, while oil gas needs only the removal of the tar and sulphur. Therefore, since the coal gas by-products cover those obtained from any other gas, we can sum up the commercially valuable substances produced from gas manufacture as

1. Gas, about 10 000 cu. ft. from ton of coal.
2. Coke, about 1 350 lb. from ton of coal.
3. Tar, about 13 gal. from ton of coal.
4. Ammonia, about 5 lb. pure NH_3 gas from ton of coal.
5. Cyanogen, about 2 lb. ferrocyanide of potash from ton of coal.
6. Sulphur, varies with coal.
7. Retort carbon, varies with heats, etc.

The gas, coke, tar and ammonia are all very valuable and constitute the main source of revenue. It is useless to recount the applications of each except to remind you that modern organic chemistry was begun largely by studying the properties and constitution of coal tar. I will therefore omit a more detailed description and pass on to the

Station Meter.

The gas after passing the purifiers is ready to sell, except that the amount made must be determined in order to keep the several parts of the works under control. This measuring is usually done by means of a large four-compartment drum, which revolves in a cast-iron case filled about two thirds full of water.

The inlet and outlets of the drum compartments are so arranged that when the outlet is *below* water, the inlet is above and the compartment fills with gas. The drum revolves something like a squirrel cage, and shortly after the inlet dips below water the outlet comes above and the compartment discharges its contained gas. The cubical contents of the compartments being accurately known, the motion of the drum is communicated by gearing to the dial, and thus we have an apparatus which accurately measures the gas made. It is customary to make proper corrections for temperature and barometic pressure, and we reduce the gas manufactured to 60 degrees fahr. and 30 in. barometer height.

On account of the large size of station meters various forms of proportional meters have been tried. These measure only a small fraction, usually 1 per cent. of the make, and are arranged to register the total, but so far there is no absolutely reliable proportional meter on the market.

A new form of station meter called the rotary is now on the market and is said to be satisfactory. It is in principle of the anemometer type, and as it is much smaller than the old-style meters it bids fair to find extended use. I question its absolute accuracy, however, very much.

Leaving the station meter the gas passes into the

Gas Holders.

These are the storage reservoirs for gas, and allow us to manufacture uniformly during the 24 hours of the day. The rate of send-out is constantly varying, but the holder takes care of that.

Gas holders are now usually constructed of steel throughout, and can be bought up to 20 000 000 cu. ft. capacity. In St. Louis we have two 4 000 000 ft. holders, and I will give you a few of the principal points of such a construction.

Diameter of tank	210 ft.
Depth of tank	34 ,,
Height of holder	160 ,,
Steel work required	2 200 tons

Cost, about $250 000 complete.

These holders are designed to safely withstand a wind load of 25 lb. per square foot on the full exposed diametrical section at full height, and a snow load of 5 lb. per square foot of the upper area, considered as being entirely massed on one edge of the crown.

For a more complete discussion of these immense structural steel holders I will refer any one interested to an article I wrote for the *Wisconsin Engineer* in 1901. There is now only one more subject I wish to touch upon before leaving the manufacturing end, and that is,

Chemistry and Photometry.

The gas business is essentially the business of a chemist. Where do we find richer fields for investigation or better scope for that research for economy than in this industry? Take ordinary coal gas. It is composed largely of some eight or ten substances, but there are traces of numberless organic changes, decompositions and formations during its evolution in the retort. Ammonia, cyanogen and tar afford unlimited possibilities, to say nothing of the analyses of the crude substances, coals and oils.

Then in a works there are flue gas analyses and numberless thermochemical reactions to be investigated. I have been in this business for years, and have devoted a great deal of study to it, and yet to-day I feel as if I were at the threshold of an unknown world timidly seeking light. For instance, we must find a cheap way to manufacture natural gas artificially, that is CH_4, and yet no one has so far found it.

Photometry is likewise in a rather unsatisfactory state. We read of mean spherical candle-power, of the Harcourt pentane lamp, the Hefner amyl-acetate standard or a standarized electric incandescent unit, and yet these ultimately refer to a sperm candle of certain physical characteristics and burning at a certain rate as the basis of comparison. Let us question a little deeper, and ask what is the real nature of that standard light, and how can we satisfactorily compare it to, say, Peter Cooper Hewitt's mercury vapor lamp? I leave it to you to ask if there is work ahead in this line.

Leaving now the first great division of the gas business, viz., manufacture, I will take up

Distribution.

This subject will be treated in a very short manner. The gas mains mostly used to-day are of cast iron, but clay, wood and

steel pipes have all been tried. An ordinary system consists of large mains even up to 48 in. and 60 in., leaving the works and acting as feeders. The secondary mains may be 6 in., 4 in. or even less, but in large cities the practice is rapidly tending to a minimum size of 6-in. cast pipe. In these cases the gas pressure is only from 1 to 2 or 3 oz. per square inch, and the natural result is that with a rapidly growing business the sizes of pipes soon prove insufficient. The remedy in former times was to build district holders and thus help out the pressure, but nowadays more economy is necessary.

I can best illustrate the case by telling how we are handling this problem in St. Louis. We first ran a 24-in. belt line around the city, passing all the gas works and near all present district holders. This is so arranged that the gas made at the works is pumped into this line at 5-lb. pressure per square inch. During the night after 10 P.M. and at periods in the day time, the district holders are filled by merely opening valves and allowing the 5-lb. pressure to force the gas into them.

Then at meal times and especially in the evening about six o'clock, when the peak load occurs, all holders are full to keep the pressure up in the low-pressure system. At various points in the city, where formerly district holders would have been placed to keep up the pressure in the neighborhood, we now use pressure-reducing governors from the 24-in. 5-lb. belt line. These governors are placed in manholes in the street, and serve the purpose of district holders as far as the pressure is concerned remarkably well, besides being so cheap to install.

For serving the belt line we use positive rotary blowers, in some cases direct connected to gas engines, since such blowers have their limit of reasonable efficiency near 5-lb. pressure. If we had desired to use 10 lb. we should either have been obliged to use two rotary blowers in series or blowing engines. For city use, where electrolysis is so frequently met, we did not feel safe in going over 5 lb. nor did we deem it wise to use anything but cast-iron pipe.

For reaching suburban communities, however, we compress the gas up to anywhere from 20 to 50 lb. pressure per square inch. Large quantities of it can then be transmitted a long distance through comparatively small pipe, and for this work screw pipe is usually employed. The reduction to working pressure is accomplished either by district governors or a governor at each house.

The whole system resembles nothing so much as an electric

alternating current distribution. The high-pressure lines take the place of the high-tension primaries, the governors of the transformers and the low-pressure pipes of the low tension secondaries.

For supplying the individual consumer small service pipes are run, and are generally 1.25 in. to 2 in. steel or wrought screw pipe.

One of the great bugbears of underground piping to-day is the electrolysis action resulting from the return currents of the street railway systems. At places in St. Louis it is very severe. The remedies suggested have been, better rail bonding, connecting the pipes and rails by wires at certain points, insulating pipe joints, covering the pipes with pitch and by other non-conductors, and others, but these are not remedies; they merely postpone the fatal day of trouble.

It may be the real way to accomplish the result permamently is for the street railway system to adopt alternating current traction, and it is to be hoped that those who are working on this problem will succeed in demonstrating the practicability and desirability of this system in respect to electrolytic action.

Consumers' meters are next in order. These little machines, which are so often maligned and said to work while the gas man sleeps, are really very ingenious and accurate instruments. They are usually of the dry type, having a partition in the center, and on each side tin disks vibrate back and forth. These disks are connected to the center plate by leather diaphragms, and the gas passes in and out through little slide valves like those on simple steam engines. The cubical contents between these disks and the meter plates are accurately known, and the vibration back and forth moves the index on the dials by means of gearing. I will now consider a few of the appliances by which gas is consumed.

Appliances.

The Welsbach light has been an important factor in maintaining gas for illuminating purposes in face of the electric light. Its spectrum is as near to sunlight as any electric device yet produced, except, of course, the Nernst lamp, which is practically the same. Gas will probably be used for lighting purposes for a long time to come, but its most rapid advance of late is in the fuel field. Gas stoves, gas water heaters, metal melters, industrial fuel devices, and even house heating, preferably by hot water systems with gas fires in the furnace, together with innumerable other appliances, are all so well known that it is useless to describe them.

A recent and rapidly increasing development in gas engines is very noteworthy. Already the steam engine and steam turbine are left far behind in the race for thermal efficiency, and that with the gas engine hardly started. We can reasonably hope for a thermal efficiency of 50 per cent. before long. Then the possibilities of the gas turbines are hardly dreamt of to-day.

Gas engines of 5 000 h.p. are in use to-day. Their operation is very satisfactory, and their regulation is so close that alternators driven by separate engines are readily kept in step.

In conclusion I will say that I realize that I have probably passed lightly by those portions of the gas business which may be of greatest interest to the general public, and have dwelt on such things as thermochemistry, heat reactions, etc., to a great extent. But I did this with the complete consciousness that I was addressing a body of intelligent engineers, and my object was to at least partially demonstrate the fact that there are many worlds to conquer in the gas business as well as in other lines, even though the progress made so far will compare favorably with other scientific achievements. Our great universities are establishing courses in chemical technology, our great manufacturing establishments are conducting experiments on gas producers and gas engines (may we say gas turbines?) and the engineering fraternity at large is more interested than ever before in gas developments.

I wish to extend a hearty invitation to any member of the Engineers' Club who may wish to inspect our plant or investigate any portion of our business, to visit us, and will welcome a chance to be of service in this line.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk St., Boston, by July 15, 1907, for publication in a subsequent number of the JOURNAL.]

PEAT COKE.

By Max Toltz, Member of the Civil Engineers' Society of St. Paul.

[Read before the Society, March 11, 1907.]

In his address delivered at the Minnesota State Fair, St. Paul, Minn., on September 3, 1906, Mr. Jas. J. Hill, president of the Great Northern Railway Company, stated that "according to dependable authority our main available coal supply will not give more than a century of life. The estimated life of the Pennsylvania anthracite coal fields, whose narrow area has permitted closer approximation, is put at little more than fifty years. The larger supply of soft coal has to answer the demand many times as great.

"It is certainly a moderate statement to say that by the middle of the present century, when our population shall have reached the two hundred million mark, our best and most convenient coal will have been so far consumed that the remainder can only be applied to present uses at an enhanced cost, which would probably compel the entire rearrangement of industries and revolutionize the common lot and common life. This is not a mere possibility, but a probability, which our country must face."

This statement comes from a man of international fame and of a knowledge on national economics sufficient to warrant its correctness. It is the province of the engineer to devise means of overcoming this shortage of fuel or, in other words, to provide measures by which the supply of heat material can be prolonged.

What can he do, what must he do, to substitute a material from which heat can be generated? Without heat there is no energy, and without energy there is no life. First of all he should stop the waste of valuable material and learn to economize. It is well known that the heat produced from coal is utilized only to the following extent:

7 per cent. in a good slide valve engine;

8 per cent. in a plain Corliss engine;

9 per cent. in a compound engine;

11 per cent. in a steam turbine; and

12 per cent. in a reheating compound or a triple expansion engine.

Although in European practice during the last ten years these values have been increased to 16 per cent. by the use of highly superheated steam, it is only during the last year that a movement towards this great economic feature has been started in our country. Yet this is only one of the features of fuel economy. What amount of heat and energy is being lost by the escaping gases of iron and steel furnaces and coke ovens which should be and probably will be converted into hundreds of thousands of horse-powers by gas engines? Lignite, the lightest coal and the greatest gas producer, will surely demand the adoption of suitable gas engines for power purposes. On oil and natural gas for heat utilization no great reliance can be placed as the supply is getting smaller all the time. The thousands of immense water powers, still hidden in the virgin wilderness of our great mountains and elsewhere, must be harnessed to do our bidding. The heat of the sun can be stored, as has been proved in isolated cases. We shall have to *utilize* the power of the ocean wave, and even the wind should be called upon to come to our assistance. But the exhaustion of the coal measures will not finish the fuel supply because there is a material which easily and successfully will supplant coal for fuel and of which there is a great abundance in our country. This material is peat, not in its original form, air-dried or compressed, but peat converted into coke. Although enterprises have sprung up to make peat briquettes a substitute for coal, every one has gone under, due to the cost of transportation and the difficulty of getting rid of the 80 per cent. to 90 per cent. of moisture which is contained in the excavated peat. No compression machine has been able to squeeze out more than 25 per cent. of this moisture. The sun and the wind must do the rest. Mechanical means of drying have been tried but found too expensive. Coke made from peat is quite a different proposition, because it concentrates the heat-bearing masses and makes this fuel less bulky. The following description of this new process will present an interesting phase of the future fuel, but before going further into details of the production of peat coke it will be necessary to review the quantities of raw material from which coke could be manufactured.

According to reports of the state geologists, the main peat beds or bogs are located in the middle West, in some Eastern states and in the South. In fifteen states reported, the total area amounts to 7 000 000 acres, with an estimated average depth of 10 ft. A conservative estimate of the total area in the United States will show about 10 000 000 acres of peat beds.

Each acre for 1 ft. of depth of peat will yield 492 tons of air-dried peat containing 20 per cent. of water, and this converted will give 164 tons of the best coke having the same heating value as charcoal, 14 500 B.t.u. The average coal contains about 11 500 B.t.u., the medium between West Virginia coal with 14 000 B.t.u. and Illinois and Iowa coal with 9 000 B.t.u. The value of peat coke is, therefore, 26 per cent. greater, or, in other words, one ton of peat coke equals 1.26 tons of coal. The total output from 10 000 000 acres of peat 10 ft. deep (surely a low estimate, as many of the peat beds have a depth of from 20 to 30 ft.) will be 16 400 000 000 tons of coke which have a value of 20 664 000 000 tons of coal. At the present rate of coal consumption, which is 350 000 000 tons per year, this peat coke would last nearly sixty years. This fuel can be furnished at a great deal cheaper cost than coal, which will be seen later on.

Peat is the partially decayed and compacted remains of mosses and other marsh plants which have become covered with water during the process of decay. Generally the plants grow luxuriantly at the surface but die below and are submerged. The rate of growth is estimated to vary from 1 to 4 in. per year and the depth of beds often exceeds 20 ft., but 10 ft. is more common. The deposits are confined to temperate regions in both northern and southern hemispheres.

At a short distance below the surface the peat is brown and somewhat loose in texture; at greater depths it becomes dense and nearly black, and in many cases it becomes lignite.

In the digging of peat for fuel the bog is partly drained by open ditches and when the excess of water has disappeared the loose surface is removed either by hand or machines.

Owing to its bulkiness peat cannot be shipped profitably to great distances. "The charcoal made from compressed peat is superior to wood charcoal and even compares with coke" (*Americana*).

This latter statement is not correct; it should read "it is superior to coal coke and even compares with wood charcoal." The comparative analysis of peat coke and charcoal is given below.

The peat is excavated with power-driven machines which deliver the material in briquettes 4 in. square and 10 in. to 12 in. long. These are deposited on boards of a size easy to handle and are forwarded either by narrow-gage wagon trucks or by belt conveyors to a place where they are stacked up like brick for air drying. As these briquettes coming from the beds contain

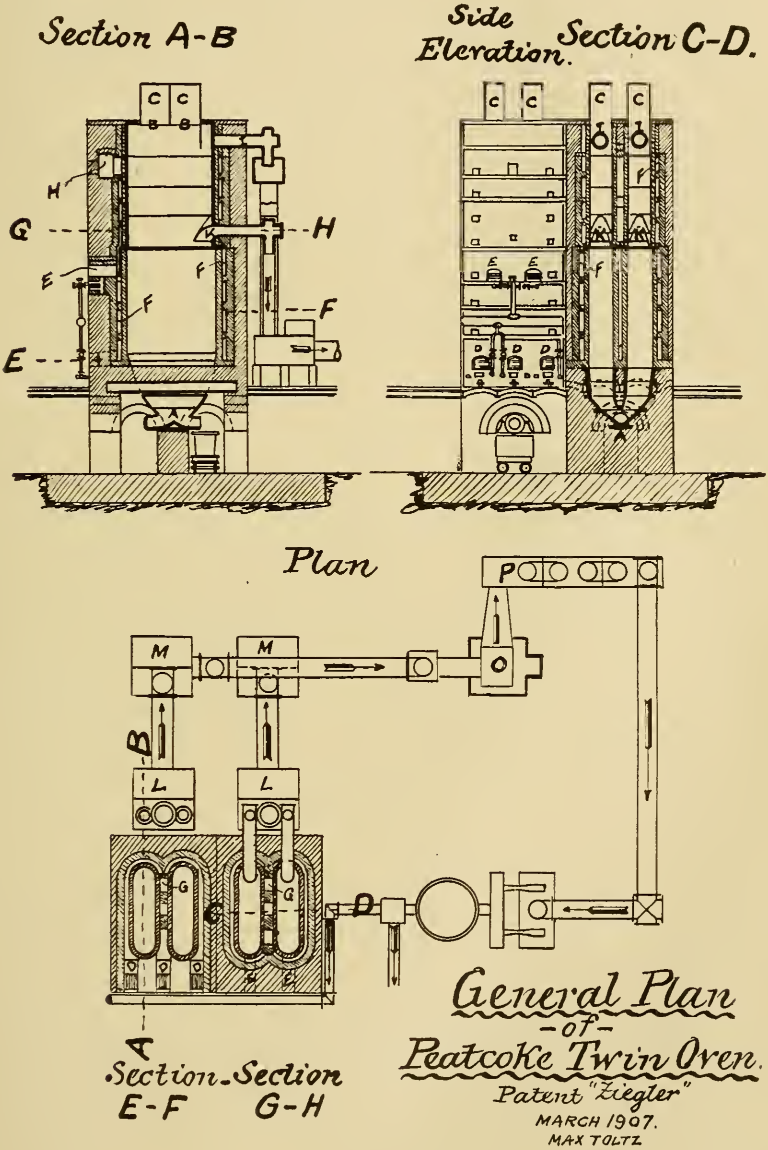
about 80 per cent. to 90 per cent. of water, the air drying will reduce the moisture to about 40 per cent. to 50 per cent. From here they are carried into air-drying chambers where solely by means of the heat given off by the coke-converting ovens the moisture is reduced to 20 per cent. In order to obtain 100 tons of peat containing 20 per cent. of moisture, it is necessary to dry within 24 hr. 200 000 briquettes or 160 tons, half of which is water, which means that 60 tons of water must be evaporated.

The escaping flue gases of the coke ovens having a temperature of about 500 degrees fahr. and being collected by means of a Sturtevant fan are cooled in a mixing chamber to about 160 degrees fahr. This must be done because dry peat can be readily ignited at a temperature of about 260 degrees fahr. About 12 000 cu. ft. of 160 degrees fahr. air per minute are therefore compressed and delivered into the air drying chambers by the fan, which amount is sufficient for the evaporation of 60 tons of water in 24 hr. By means of a slide or butterfly valve the quantity of air passing into the individual chambers is easily regulated. The saturated air at a temperature of about 90 degrees fahr. escapes through chimneys to the atmosphere.

The peat briquettes are fed to these chambers at the top in the same quantities as they are removed from the bottom. These chambers, therefore, are constantly being replenished with briquettes, and their passage is so governed that every particle of peat is subjected to the hot air for at least 24 hr.

From here the dried peat briquettes are moved by conveyors to the top of the coke ovens. These are built in twins, having elliptically shaped retorts of firebrick in the lower half and of cast iron with a thin outside lining of firebrick in the upper half. These again are surrounded by another firebrick shell, leaving an air space which is divided by walls into fire flues. The whole oven is then protected by a common brick wall. The retorts rest upon a cast-iron foundation and end in a hopper "A" (see "General Plan of Peat Coke Twin Oven"), which has two openings for drawing off the peat coke. Each of the retorts is closed on top by cast-iron covers "B" which carry the feed boxes "C." The openings through which the peat is fed and the coke is drawn off are air tight. The dimensions of these ovens are such that in 24 hr. 18 tons of air-dried peat containing from 20 per cent. to 25 per cent. moisture can be converted into coke. The non-condensing gases which are generated in sufficient quantities are used for the firing of the ovens and are fed into the combustion chambers through three lower "D" and

two upper " E " openings, passing thence through the fire flues (" F " and " G ") to the collecting flue " H," which leads to the exhaust fan of the mixing chambers. For every fire flue a peep-



hole on the front and rear side of the ovens is provided for the purpose of watching and taking the temperature, which in the lower flues generally mounts to 1900 to 2000 degrees fahr.,

and in the upper ones to about 1100, 900 and 700 degrees fahr. respectively. The escaping fire gases, as mentioned before, are drawn to the mixing chamber, from which they are led to the drying chambers to be employed for the final drying of the peat briquettes.

The highest temperature in the ovens reaches 1100 degrees fahr. The heat of the products of distillation (water vapor and tar gas) which pass through the pipes " I " and " K," at a temperature of from 360 to 540 degrees fahr., serves to dry by evaporation in the vessels " L " and " M " the ammonium sulphate and acetate of lime solutions from the tar water.

To start the process the ovens must first be fired with peat after they have been filled with the air-dried briquettes. Within 48 hr. sufficient non-condensable gases are given off so that peat firing can be discontinued and the gases ignited. The air necessary for combustion is previously properly heated by the cast-iron hoppers which at the same time serve the purpose of cooling off the peat coke in them.

The regular *modus operandi* is now pursued as follows:

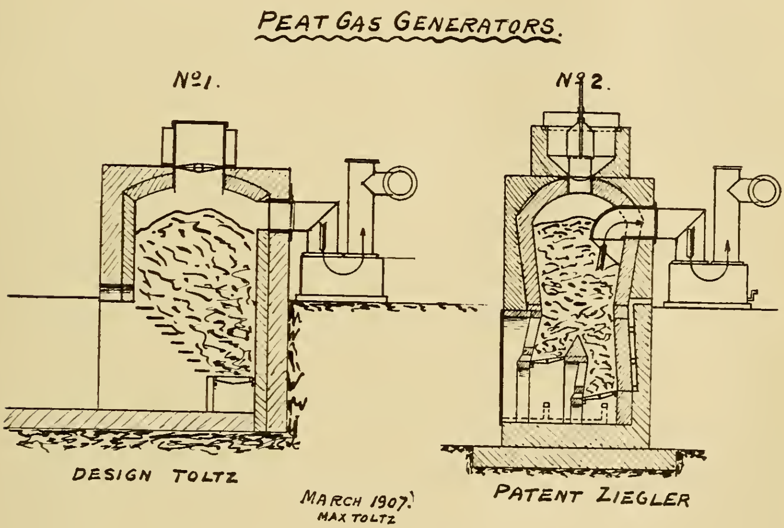
The peat coke is hourly drawn off from the hoppers into air-tight, steel wagons in which the coke must be permitted to thoroughly cool. After each withdrawal of coke fresh supplies of peat briquettes must be fed to the ovens by means of the feed boxes on top. The operation thus becomes a continuous one. In this process of converting peat into coke (dry distillation) the water vapors and tar gas generated are collected by the exhaust fan " O " and driven through the pipe condenser " P," in which by reason of contact with the air, they are condensed to tar and tar water. These two by-products are valuable and are converted into different chemicals which will be described later.

The non-condensable gases are compressed by means of another fan and in this state find employment as fuel for the firing of the ovens and such boilers as may be installed for purposes of this process.

For a consistent operation it is important to obtain the peat as cheaply as possible. The peat machines or excavators should, therefore, be driven by electric motors instead of by individual steam boilers and engines. For the generation of electrical power, gas motors are best employed which are run with peat generator gas. A further advantage is that such a plant is centralized and need not be moved when the location of the peat machines is changed. Peat refuse and such peat as is not suitable for coking answer very well for this purpose in a peat gas generator.

The sketches below show two types of generators.

The first one was designed by the writer and was used years ago in connection with ovens for glass manufacture in the northern part of Germany. The second one was designed by the inventor of this peat coke process. In one hour, from one ton of fairly dried peat, 90 000 cu. ft. of gas of about 140 B.t.u. each are generated. Per horse-power per hour, at the very highest 90 cu. ft. of generator gas are used in a gas motor, so that with this generator a gas motor of 1 000 h.p. is provided with fuel. One thousand cubic feet of generator gas cost, at the most, 3 cents, and 1 h.p. per hour can be obtained for one third of one



cent. By the operation of an electrical power plant, one ton of machine peat will come to $1.18 as per detail cost below. The daily output of 33 tons of peat coke requires 100 tons of air-dried peat briquettes per day, or 36 000 tons per year. On account of climatic conditions in the northern states, atmospheric drying of peat is limited to a period of 100 days; therefore a certain number of peat machines should be worked day and night during this period.

As one machine has a capacity of 30 tons of peat per 10 hr., it will be necessary to run six machines day and night for 100 days to work up a year's supply. One machine should be held in reserve. Each machine is attended by 14 men and one foreman. The cost of air-dried peat briquettes will therefore be:

Daily Wages at Peat Machines.

156 men, per day, $2.00	$312.00
12 foremen, per day, $3.00	36.00
For output of 360 tons, daily wages	$348.00

Expenses for 36 000 Tons Air-Dried Peat Briquettes in 100 Days.

Wages at peat machines	$34 800
5 per cent. repairs on $10 000 (cost of 6 machines)	500
Power to run machine	1 200
15 men transporting and storing briquettes	3 000
15 men turning and stacking briquettes	3 000
Actual cost of 36 000 tons	$42 500

or $1.18 per ton of air-dried peat briquettes, as stated before.

Cost of Plant, Daily Capacity 100 Tons Air-Dried Peat, Yielding 33 Tons Coke No. 1.

3 twin ovens	$60 000
Machinery, etc.	24 000
Apparatus for distilling tar water, etc.	20 000
6 peat machines	10 000
Total	$114 000

Before final cost of coke can be established the yield of by-products from the tar and tar water must be considered.

The following diagram gives the percentages of chemicals extracted:

Air-Dried Peat Briquettes = 100 Per Cent.

33% Coke No. 1.	4.5% Tar.	46.6% Tar Water.	15.9% Gases.

2% light Oils	0.7% heavy Oils	0.3% Paraffine.	1.3% Crude Carbolic Acid.	0.2% Asphalt.
4.5%				

0.34% Wood Alcohol.	0.31% Ammoniac Sulphate	0.5% Acetate of Lime.	45.45% Water and Losses.
1.15%			
46.6%			

One hundred tons of air-dried peat briquettes will yield 4.5 tons of tar and 46.6 tons of tar water, which can be manufactured into the following by-products having a value of:

975 lb. ammonium sulphates	per cwt.,	$3.07	$29.93
1 420 lb. acetate of lime	,, ,,	2.35	33.37
72 gal. wood alcohol	per gal.,	.70	50.40
280 gal. light oil	,, ,,	.10	28.00
95 gal. heavy oil	,, ,,	.10	9.50
350 lb. paraffine	per lb.,	.05	17.50
1 580 lb. crude carbolic acid	,, ,,	.03	47.40
175 lb. asphaltum	,, ,,	.01	1.75
Total value of by-products			$217.85

The daily cost of operation of a plant of three twin ovens, having a capacity of 100 tons of air-dried peat briquettes, or 33 tons of coke No. 1, is:

100 tons of air-dried peat briquettes at $1.18	$118.00
38 men, $2.00 per day	76.00
2 foremen, $5.00 per day	10.00
1 chemist	8.00
Interest and depreciation on $114 000, per day (300 days per year)	57.00
	$269.00
General expenses, 7 per cent	18.55
License, per day	7.00
Royalty, per ton coke, 10c	3.30
Total expenses	$297.85
Less value of by-products	217.85
Actual cost of 33 tons of coke No. 1	$80.00

or $2.42 per ton of coke No. 1.

All figures given are conservative and, no doubt, could be reduced from 5 per cent. to 10 per cent. The prices for the by-products are charged intentionally low.

The following are the market values:

Light oil, per gal., 32c.; charged out at	10c.
Heavy oil, per gal., 14c.; charged out at	10c.
Paraffine, per lb., 10c.; charged out at	5c.
Crude carbolic acid, per lb., 11c.; charged out at	3c.
Sulphate of ammonia, per lb., 7½c.; charged out at	3c.

The relative fuel value of the peat coke and the best charcoal is shown by the following analysis:

Comparative Analysis.

		Peat Coke No. 1.	Charcoal.	Peat Coke No. 2.
Carbon	C	86 to 87.7	87.7	73.89
Hydrogen	H	1.9 to 2.0	3.1	3.59
Nitrogen	N	1.3	0.4	1.49
Oxygen	O	5.2 to 5.5	4.7	0.20
Sulphur	S	0.3	0.3	14.52
Ash	A	3.0 to 3.2	0.9	2.50
Water	H_2O	.0 to 4.3	3.0	3.80
Caloric value (Metric system)	WE	7 800	7 800	6 700
British thermal units, B.t.u.		14 500	14 500	12 450

So far only peat coke No. 1 has been considered in detail, but a lower grade of coke can be manufactured by this process,

which is called peat coke No. 2. The yield of this latter from 100 tons of air-dried peat briquettes is 45 tons instead of 33 tons, as in the case of coke No. 1.

The Use of the By-Products of Peat.

(1) *Peat Coke No. 1.* — This coke can replace charcoal and can stand the same pressure in a puddle or iron furnace as the best coke made of coal.

(*a*) It can be used in the manufacture of charcoal iron and all such iron as should have a high ultimate strength. Charcoal cannot be bought for less than from seven to eight dollars per ton in the different states at the different charcoal plants. Peat coke can be manufactured at the low cost of about $2.50 per ton, and could be readily sold at from $3.50 to $5.00 per ton. At the present time there are about 180 furnaces working with charcoal in the United States.

(*b*) It is used in the manufacture of zinc, lead and copper, and can be easily introduced because it can replace charcoal.

(*c*) For soldering and welding, this coke develops a highest heat and is most economical.

(*d*) To harden armor plates, this coke in powder form is used in Russia, France and Germany.

(*e*) According to experiments made by Siemans and Halske the best calcium carbide is manufactured from this coke.

(*f*) On account of the quick ignition, this coke in powder form is the best material for firing furnaces in manufacturing cement, pottery, etc.

(2) *Peat Coke No. 2.* — This coke is used for firing locomotives on the Nikolai Railway in Russia. The Russian government is now making tests with this coke for firing the boilers of battleships and torpedo boats. The state railway of Bavaria is also introducing this coke for firing locomotives. It is also used generally for commercial as well as domestic purposes.

(3) *Peat Tar.* — On account of its containing nearly 30 per cent. of creosote this tar can be used directly for impregnating ties and timbers. In Sweden the railroads are dependent upon this product for impregnating purposes.

(*a*) The light oils distilled from this tar can be used either for illuminating purposes or in the manufacture of oil gas, while the heavy oils are used for lubricating purposes.

(*b*) Paraffine, the consumption of which is increasing every year, has a wide field in the manufacture of electrical apparatus, etc.

(*c*) Phenol is carbolic acid in the raw and liquid state.

(*d*) Asphaltum is used for paving compositions, paints, etc.

(4) *Tar Water.*

(*a*) Wood alcohol has the same composition as methyl alcohol, and is used for the same purposes, especially in the manufacture of methyl colors.

(*b*) Sulphate of ammonium is the substitute for manure and is used especially in the manufacture of smokeless powder; also for making ice. The production of the whole world in 1900 was 493 000 tons, 210 000 tons of which were manufactured in England, 120 000 in Germany and the balance in other countries.

(*c*) Acetate of lime in the form of brown or gray lime is used in distilling acid salts and pure vinegar.

The process of converting raw peat into coke, as here described, was invented by the German mining engineer, Martin Ziegler, who is an expert on coke manufactured from low-grade coal. To him belongs the credit for devising means whereby all products of peat are used economically, the main issue being the utilization of the gases for firing. This process can also be used for converting lignite into coke.

The first installation on a larger scale was made in 1894 at Oldenburg, Germany, but many changes in the details have been made since that time to perfect the process. This has been done, and since 1902 several plants have been built in Russia, Sweden and Germany, the most recent and modern being the one at Beuerberg, Bavaria, which has a daily output of 200 tons of coke No. 1. The success which has been accomplished in Europe will tend to hasten the introduction of this process in this country for the purpose of obtaining a first-class fuel at a moderate cost and making useful the vast peat beds of the United States.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by July 15, 1907, for publication in a subsequent number of the JOURNAL.]

DIFFICULTIES ENCOUNTERED IN EARLY SURVEYS OF THE STATE OF MASSACHUSETTS; HOW THEY WERE OVERCOME AND THE RESULTS OBTAINED.

By Frank W. Hodgdon, President of the Boston Society of Civil Engineers.

[Read before the Society, March 20, 1907.]

In these days when engineers have every aid and opportunity to do their work, it is well to occasionally look back and see how our predecessors had to work, how in many instances they were compelled to construct instruments and tools which can now be purchased at any time. The present facilities for traveling and communication make many tasks easy which in earlier days were quite difficult.

I have recently had occasion to study somewhat the reports and papers of some early surveyers engaged on the Massachusetts State surveys, and thought it would be interesting and instructive to give you some account of the difficulties they encountered, how they overcame them and the results they achieved.

Northern Boundary.

In 1740 King George II decreed that the northern boundary of Massachusetts should be a line 3 miles distant from the north bank of the Merrimac River from the sea to a point 3 miles north of Pawtucket Falls, and thence due west to his Majesty's other possessions.

Governor Belcher of Massachusetts and New Hampshire was ordered to have the line run and marked, and he employed Richard Hazzen to run and mark the straight line west of the point 3 miles north of Pawtucket Falls. This he proceeded to do in the months of March and April, 1741.

The country was largely a wilderness, heavily wooded.

The party, consisting of Mr. Hazzen and six assistants, started Friday, March 20, from his house at Haverhill and reached Colonel Varnum's, near what is now Lowell, about 9 A.M. the next day, having lodged over night at the fireside of Mr. Richard Hall in Tewksbury. At Colonel Varnum's they met George Mitchell, who was to run the line 3 miles north of the river from Pawtucket Falls to the sea. In his company the distance, 3 miles north from Pawtucket Falls, was measured and a pitch

pine-tree marked; this point is now marked by a granite monument known as the Pine-Tree Monument. In the afternoon Hazzen ran the line west 1 mile 16 rods, making an allowance of 10 degrees for the variation of the compass. His party rested on Sunday, lodging with friends, and went to church twice. They started again Monday and ran generally 4 to 6 miles each day, including Sundays, except one, April 5, at Northfield, on the bank of the Connecticut River, where they went to hear Rev. Mr. Doolittle preach both parts of the day.

The following extracts from Mr. Hazzen's diary are a fair sample of the whole:

"Friday, April 10. This day we measured 2:1:20.

"*Remarks.* At the end of half a mile from where we set out this morning we came to Deerfield River, very high and steep mountains being on each side of it, and up and down the river as far as we could see. We met with great difficulty in passing that river, first attempting to wade, and one only got over, and then tried to raft, but it was so shallow in some places we could not use it, and at length we found a place where we all waded over, though with great hazard, the water ran so swift. The mountain on the west side was so steep that we could not carry the chain to measure, but in 4 or 5 hr. time, when we had ascended the top of it, we judged we had got forward on our course 40 poles and no more at the furthest. The snow this day was about 3 ft. deep, the weather fair and the wind northwest. At about sunset we left off measuring and built a fire on the snow and lodged by it.

"Saturday, April 11. This day we began to measure before sunrise and measured 7:0:00.

"*Remarks.* At the end of 4 miles, 3 quarters and 20 poles we came to a small river running north, and where we crossed the river was good intervale land on both sides and a large English camp a little north of the line, and on the east of said river and at the end of 7 miles two large brooks met. One came out of the westward and the other northward and then ran southeasterly.

"We thought both these streams might be branches of Deerfield River and that the camp was made by Captain Wells and company. The land all this day's course was good and fit for settlements, the snow about 3 ft. deep and where we lodged about 5; we lodged where the two brooks met and there we left our bottle, therefore called it Bottle Brook. It snowed a little the greatest part of the day and the wind was northeasterly.

"Sunday, April 12. This day we measured 4:1:50.

"*Remarks.* At the end of 3 miles we came upon the top of an exceeding high mountain, from whence we discovered a large mountain which lies southwesterly of Albany, as also a row of large mountains on each side of us bearing north and south nearest, and a ridge of exceeding high mountains 3 or 4

miles before us bearing the same course, and a fine valley betwixt them and us on each side of the line big enough for townships. At 130 poles further we crossed a branch of Hosek River running southerly, thence to main river Hosek running northwesterly. With difficulty we waded it and lodged by it on the westerly side that night. The first part of the day was good traveling, but heavy by noon, and betwixt the two rivers the snow was almost gone. It clouded over before night and rained sometime before day, which caused us to stretch our blankets and lie under them on the bare ground, which was the first bare ground we laid on after we left Northfield. There was but little wind this day.

" Monday, April 13. This day we measured from Hosek River 4:2:0, which was only over one mountain.

"*Observations*. This mountain was exceeding good land, bearing beech, black birch and hemlock, some bass wood. Over this mountain we concluded the line would run betwixt these and New York government whenever it should be settled, and therefore name it Mt. Belcher, that it might be as standing a boundary as Endicutt's tree. We lodged again on a bare spot of ground by a brook running southwesterly, which being full of clay we named it Clay Brook. We had some thunder showers in the night which obliged us to rise and stretch our blankets. The weather was cloudy all day and no wind stirring and the snow for the last 3 miles about 2 ft. deep — the first mile and a half but little.

* * * * * * * * * ° *

" Thursday, April 16. We measured to Hudsons River 5:0.

"*Observations*. On a small mountain at 4 miles and 40 poles from where we began to measure this morning we had a fair view of the city of Albany bearing from us southwesterly and distant about 8 miles as we judged, and at the same time had as fair a view of the fall of the Mohawk River, called Cohoes or Great Falls above Albany, to our very great joy, and therefore named the hill Mount Joy, the said falls being distant from us 3 or 4 miles; from thence we kept our course to Hudsons River at about 80 poles from the place where the Mohawk River comes into Hudsons River. We went thence to Albany and tarried there that night. The trees standing in our line or near it are well marked, but could raise but few other monuments, the snow in most places having covered the stones. The rivers and streams and ponds are laid down in their proper places exactly where we crossed them, but out of sight altogether by guess. The mountains are laid down as much in form as I could, and many pretty exactly, but they being of such a vast extent it must not be concluded that they are all so perfectly done nor that they are all put down that came within sight.

" Friday, April 17. At 9 o'clock we left Albany and the same night came to Kinderhook, and that night lodged by Derrock Slake's fire.

* * * * * * * * * * *

"Friday, April 24. It rained hard most of the day, yet we traveled from Harvard to Groton, where William Richardson, one of the company, left us and went to Townsend, where he belonged, the rest of us to Dunstable, where we lodged that night.

"Saturday, April 25. I purchased a canoe at Dunstable and came down the Merrimack River to Dracut. We carried our canoe over Pentucket Falls. Zechariah Hildreth, another of our company, stopt at Dracut, where he belonged. We came down the river thence to Methuen, where Mr. Caleb Swan, another of the company who belonged there, left us. The rest of us came to Haverhill about 8 or 9 o'clock, after a journey of 37 days, all in perfect health through God's goodness to us.

"RICHARD HAZZEN.

"N.B. — The weather proved so favorable that we never stopped in the woods for any foul weather, nor did we make a camp any one night and stretched our blankets but three times all the journey, but lodged without any covering save the heavens and our blankets."

The distance was one hundred and ten miles each way and was done in 37 days.

In 1825 the line east of the Connecticut River was resurveyed by Caleb Butler and Benj. F. Varnum, representing Massachusetts Commissioners, and Eliphalet Hunt, representing New Hampshire Commissioners. They found the line marked by Hazzen, and in 1827 Mr. Varnum set granite monuments to mark the line. Between 1886 and 1900 the whole line was resurveyed and re-marked by commissioners from Massachusetts, New Hampshire and Vermont, Mr. Nelson Spofford being the surveyor for Massachusetts. Mr. Spofford's paper, "The Northern Boundary of Massachusetts," read before this Society December 21, 1904, and printed in the JOURNAL OF THE ASSOCIATION, Vol. 37, p. 1, for July, 1906, discussed the resurveys, besides giving an account of the original running of the line, similar to the foregoing narrative.

Subsequently to Mr. Spofford's resurvey the location of the various monuments is being determined in connection with the survey of the town boundaries, and this furnishes an opportunity to learn how well the original work was done.

Assuming that the line was intended to be straight from Boundary Pine to the northwest corner of Massachusetts, we find so far as the town boundary survey has progressed that none of the points are more than 1 530 ft. off the straight line.

This line was run by an ordinary surveyor's compass and the measuring done with the ordinary old-fashioned surveyors'

chain. The straight line from Boundary Pine to the northwest corner of Massachusetts is almost exactly 100 miles in length.

The line as run deviates from this straight line to the south, the greatest deviation being about 1 530 ft. at a point about 33 miles from Boundary Pine. In general the line deflected steadily to the south for the first 20 miles, reaching a point about 1 200 ft. from the line; then the general course for the next 33 miles was practically parallel to the straight line and from 1 200 to 1 500 ft. from it. In the last 45 miles the line gradually approaches the straight line, coinciding with it at the northwest corner.

Massachusetts–New York Line.

In 1785, at the request of both Massachusetts and New York, Congress appointed Thomas Hutchins, a military engineer who had served in the Revolution as geographer-general under General Greene; Rev. John Ewing, vice-president of the American Philosophical Society; and David Rittenhouse, a distinguished clock and instrument maker, a commission to run out and mark the line between the two states, and it was agreed that the boundary should be a straight line north 15 degrees, 12 min., 9 sec. east [true bearing]. This line was run along the summits of the Berkshire Hills and is about 50 miles long; it was marked by cuts in the ledges and stakes with stones piled around them where there was no exposed ledge.

The instrument work was done principally by Mr. Rittenhouse and Simon DeWitt.

When this line was resurveyed in 1897–98, most of the principal marks were found and they were all practically on a straight line,the bearing of which was north 15 degrees, 12 min., 22 sec. east, varying only 13 sec. from what it was originally intended to be. This straight line in all but one case ran through some portion of the stone piles which were built around the original stakes which had rotted away.

Along the line at various points and at the northwesterly corner of the state were found bounds which were said to mark the state line, but were 50 to 70 ft. from it. It was known that none of these were placed by the commissioners of 1785, though it was stated that some were set to replace marks which were thought to have been placed by those commissioners, but there was no definite information thereof.

This line was run with a transit from summit to summit, the instrument being reversed and the line projected ahead in

the usual way. The points set in this way are those referred to as being practically on line. Between these transit points, down through the valleys, the line was run by a compass, and at these points more deviation from the straight line was found. The measuring was undoubtedly done by the ordinary surveyor's chain.

Borden Survey of Massachusetts.

In the House of Representatives of Massachusetts, in the summer session of 1829, an order was passed appointing a committee "to consider the expediency of determining such a map or maps of this commonwealth as the public exigency requires, and report thereon to the next session of the legislature."

This committee reported at the succeeding winter session, and as a result of that report the following resolves were passed: On March 1, 1830, a resolve directing the cities, towns and districts of the commonwealth to each make a plan of its territory on a scale of 100 rods to an inch and file them with the Secretary of State before June 1, 1830. On March 30, a resolve directing the governor to appoint a surveyor to make a survey and skeleton map of the state, including the external boundaries and most prominent bays within the territory, the intention being to use this survey as an outline and ground plan on which should be plotted the information furnished by the plans made by the various towns. These town plans were made by local surveyors and filed as directed.

Under these resolves Mr. Robert Treat Paine, of Boston, was appointed chief engineer, May 13, 1830, and Mr. James Stevens, of Newport, R. I., on the 25th of June following, assistant engineer, to execute the authorized surveys and to project the map.

From time to time resolves were passed providing for agricultural, geological, mineralogical, botanical and zoölogical surveys, and these were made while the surveys for the map were in progress.

Mr. Paine undertook the necessary astronomical work to determine the latitude and longitude of a number of points throughout the state, and Mr. Stevens undertook the triangulation work to determine the relative position of enough points throughout the state, including those whose latitude and longitude were to be determined by Mr. Paine and such points as were necessary along the state boundary line, to furnish data to make an outline map of the state, on which should be plotted the topography shown on the various plans filed by the towns.

On May 31, 1831, Mr. Stevens made his first report, describing the work of similar character which had been done abroad and stating that there were only two cases of a similar class of work which had been done in the United States previous to the Massachusetts survey: "The first was the survey of the coast of the United States by Prof. F. R. Hassler, which was discontinued immediately after its commencement. The other was that of the state of Rhode Island, which had been but recently completed, and of which there has not as yet been any description given."

He then describes the method of carrying out the work, — first measuring a base line and extending the work by triangulation, describing the spherical work and the necessity for determining the latitude and longitude of various points of the survey by astronomical observations.

He then states that he had explored the location for a base line and found a suitable one on the plains along the west bank of the Connecticut River, at or north of Northampton; he had also explored the country to the west and to a certain extent to the eastward of the proposed base line.

In a later report, transmitted to the legislature on January 31, 1832, Colonel Stevens describes the base line apparatus, built for the survey by the Pocasset Manufacturing Company of Fall River, in the town of Troy, Mass., under the direction of the scientific and practical mechanic, Simeon Borden, Esq., the conductor of that establishment, and at the time a member of the legislature. The whole apparatus was designed by Mr. Borden in accordance with a rough drawing and about an hour's conversation with Colonel Stevens. The microscopes were constructed by Dr. Joseph Rice under Mr. Borden's direction. The other instruments for the survey were loaned to the state by the general government, but were without stands, side plates, etc., necessary for their use. These necessary parts were designed and constructed by Mr. Borden. The cost of the above, together with the necessary drafting tools, was less than $800.

After experimenting with young men who had volunteered for the work, Colonel Stevens finally induced Mr. Borden to leave the machine shop and undertake the measurement of the base line, and he continued with the work until the completion of the map.

Two measurements were made of the base, which was 7.3882 miles [39 009.73 feet] long, the difference of the two measurements being 0.237 in. The second measurement was

completed on the 12th of October, 1831. Then the work of extending the base line by triangulation was commenced. On March 8, 1833, Colonel Stevens describes the work of extending the triangulation, giving details of the territory covered and explored. The triangulation points, wherever practicable, were marked by copper bolts set in the ledges on the summits of the hills. The church spires in the various villages were also determined and many points along the state boundaries. During the winter and stormy weather the calculations of the survey were made. In December, 1833, Colonel Stevens made a report as to the progress of the triangulation work during the year.

The legislature of 1834 began to look for results from this survey. No maps had been made and the notebooks were incomprehensible to the members. The Committee on Education, to whom the examination of these notebooks had been referred, reported that "it appears that the survey has been prosecuted with all the despatch practicable with the perfect accuracy required in the various operations. . . . So great has been the diligence of the engineers, as the journal shows, that even Sunday has not been regarded as a day of rest — a circumstance which the committee observe with regret and which they trust will not continue. . . . The progress of this great work is necessarily slow, but we are encouraged with the possibility of its completion in another year."

The committee recommended that an appropriation be made for carrying on the work, but the matter was then referred to a sub-committee, whose report criticised the engineer for the manner in which the survey had been conducted, but indorsed the recommendation of the Committee on Education that a further appropriation be made because the engineer who, in the opinion of the committee was the only man who could advantageously utilize the work already done, had threatened to resign unless the appropriation was made.

The criticisms of the legislature were so distasteful to Colonel Stevens that, notwithstanding the fact that the legislature made the appropriation which he asked for continuing the work, he resigned his position, and on April 7, 1834, Mr. Simeon Borden, who had built the base line apparatus and constructed improvements to the other instruments, and who had also been employed as the assistant of Colonel Stevens, was appointed by the governor to continue the work.

In Senate Document No. 3 of 1835 is printed a report by Mr. Borden, describing the progress of the work from the begin-

ning up to January, 1835, from which it appears that the triangulation work was still incomplete, and he made an estimate of \$4 175 for continuing the work another year. The work continued through 1835 and 1836.

In 1836 Mr. Borden reported that his salary was \$1 500 per year, with subsistence; his two assistants received between them \$710, with their subsistence. He stated that he had personally observed all the angles of the survey, having had one recorder and one general helper. He described the difficulties he had experienced with fog and refraction in connection with the work on Cape Cod and the Vineyard, and also near the New York boundary.

In April, 1838, the final report of Mr. Paine on the astronomical observations and calculations for determining the geographical positions of 27 points was received. The field work of the triangulation of Mr. Borden had been completed, but the calculations and measurement of the verification base in the southeastern part of the state had not been finished, neither had the plotting of the map been commenced.

On February 18, 1839, a special committee of the Senate, consisting of Jeremiah Spofford, S. G. Goodrich and Jared Whitman, was appointed to inquire when a map of the state was likely to be completed, and to consider the expediency of a further expenditure for that purpose. This committee reported on April 4 that in their opinion "the state had been, in some instances, subjected to gross imposition and that expenditures have been incurred which tended little to the furtherance of the object in view." The committee did not feel that they had the data on which to found an opinion as to the competency of the several agents. They further reported that "some of the agents, finding themselves comfortably reposing upon the liberality and confidence of the state government and people, have been in no haste to bring their labors and their emoluments to a conclusion."

The committee, notwithstanding, reported, as had all previous ones, that it did not feel justified in recommending a change in the method previously adopted for completing the map.

On February 14, 1840, Mr. Borden, being then engaged in plotting the third section of the map, made a detailed report to the governor, describing the methods of executing the work and the difficulties which he had encountered.

The map was plotted on a polyconic projection, and was

divided into five sections, the first section being practically the area west of the Connecticut River, the second section extended about half way from the Connecticut River to the sea, the third and fourth sections consisting of the area between the second section and the sea, the northerly half constituting the third section and the southerly half the fourth section and the fifth section included the remainder of the state, mainly Cape Cod. In each section a central meridian line was determined and rectangular coördinates determined for all points in each section in relation to this meridian line. In addition the latitude and longitude in relation to the equator and meridian of Greenwich were determined for all the main stations.

After plotting the outline of the state and the various triangulation points, an attempt was made to complete the map by reducing the plans furnished by the various towns to the scale of the state map and then inserting them in their proper positions on the state map, using the positions of the triangulation stations, including churches and similar objects, as common points, they being shown both on the state map and on the town plans. It was found that the town maps were so inaccurate that it was impossible to complete the state map with any degree of accuracy in this manner.

In 1838 a legislative act provided that those towns which had returned inaccurate plans should have new ones made and filed in the manner provided for the original maps; but with no other data than that furnished by the plans themselves it was impossible to determine which were the accurate and which the inaccurate plans. In order to determine this, if possible, the governor authorized Mr. Borden to ascertain which were the accurate towns by measuring lines across them and comparing these distances with the corresponding distances scaled on the town maps, these measurements to be so made as to be useful in plotting the topography of the town. An attempt was made to do this with the result that nearly all the plans of towns in the western part of the state were found to be more or less erroneous. In one case, when they had nearly completed the examination of the town, they learned that no survey whatever had been made for the purpose of making the map of the town, not even an angle or a line had been measured. The selectmen had obtained from some source the bearings and length of the outlines of the town, which they furnished to the person who made the map. This person drew the outlines or boundaries of the town in accordance with the data furnished him, and the

roads, streams, etc., he merely drew upon the map with no other guide than his judgment. The measurements in this town made by Mr. Borden furnished sufficient data to correct the plan, there being but few roads in the town, most of which were measured. The plan furnished by this town was a full mile too short.

While making these examinations numerous secondary points were determined which furnished much additional information to assist in correcting and adjusting the various town plans.

The method of making several town maps, as described by the surveyors who made them, was as follows: The selectmen agreed with the surveyor to survey the town by the day, and furnished the surveyor with the bearings and lengths of the boundary lines taken from the ancient surveys. With these outlines and a survey of a few of the principal roads, he made the map, cutting off or lengthening the roads wherever necessary to keep them within the outlines as laid down from the data furnished by the ancient surveys. The unsurveyed roads were sometimes drawn by eye whereby the map of the road was made to somewhat resemble the original in its various turnings and windings. Sometimes they were merely directed by the edge of a ruler and had no resemblance to the road they were intended to represent.

Many towns contracted to have a map made for a certain sum and agreed to furnish the surveyor with the outlines and allowed the privilege of sketching many of the roads. In contrast, many towns had faithful surveys made of their whole territory and furnished very good maps, except that topographical representations were generally omitted or executed in a very imperfect manner. A few maps showed the topography very well.

The topography as finally placed on the map is due largely to sketching done in the field by Mr. Borden and his assistants.

Various methods were used for fudging the town plans to make them fit together. Plans of railroad surveys, which had then been made, were placed at Mr. Borden's disposal, and were of material assistance in helping him to adjust these town plans. With the assistance of Mr. Alvan Clark an arrangement which he calls the " Camera Lucida " was used for reducing the various maps to make them conform to the sizes required. In some cases the maps were cut into small sections and these sections either overlapped or spread apart so as to bring the total area

to correspond with the space on the state map, determined from information furnished by plans of adjoining towns or by special surveys. Some of the towns which were resurveyed by the local authorities were still so crude that they could not be satisfactorily adjusted into the state map, and had to be again resurveyed by Mr. Borden.

The map was finally completed in 1841, and a contract was made for having it engraved on copper on a scale of 2.5 miles to the inch and finished in 1842, but the engraving was delayed and the six plates, making a map 7 by 4.5 ft., were not finally finished until 1844, when a contract was made with Charles Hinckley, of Boston, to print the map and place it on sale at $5 each and pay the commonwealth $1.50 royalty for each map sold. The commonwealth itself ordered 760 copies at $3.50 each, the price to the public less the royalty.

I have not been able to learn the exact cost of the work. In 1841 the cost is given as follows:

Agricultural survey	$8 473.53
Astronomical survey	8 893.75
Trigonometrical survey	48 596.71
Geological survey, first and second editions	7 631.67
Geological and mineralogical re-examination	6 869.76
Botanical and zoölogical	4,113.45
	$84,578.87

At the same time the following estimate was made of the cost of completion:

Geological survey	$2,500.00
Botanical, etc	1 800.00
Trigonometrical, field work and plotting	2 000.00
Unpaid bills	1 760.00
	$8 060.00

The engraving was afterwards contracted for at $3 800.

Assuming that the above estimates were correct, the total cost was $96 438.67, of which $65 050.46 was for the survey and map, to which should be added the cost of the town plans, which was paid by the towns.

This was one of the first pieces of geodetic work done in the United States. The Coast Survey had previously established the latitude and longitude of certain points, which determinations they continued to use up to 1880, after which they used the results of their later observations.

Comparing the location of Prospect Hill, Waltham, as de-

termined first by the Coast Survey and later by Messrs. Paine and Borden, with the revised position adopted by the Coast Survey as the result of its observations up to 1880, we find that the position determined by the surveys of Mr. Paine and Mr. Borden to be very much nearer the revised determination of the Coast Survey than the position originally determined by the Coast Survey, as shown by the following tables:

PROSPECT HILL, WALTHAM.

	Latitude.	Longitude.
Borden, original	42° 23′ 19.25″	71° 15′ 33.76″
Borden, revised	42° 23′ 17.91″	
Coast Survey before 1880	42° 23′ 16.842″	71° 14′ 54.393″
Coast Survey after 1880	42° 23′ 18.831″	71° 15′ 15.333″

Longitude.

Borden, 18.427″ more than latest Coast Survey.
Early Coast Survey, 20.940″ less than latest Coast Survey.

Latitude.

Borden, original, 0.419″ more that latest Coast Survey.
Borden, revised, 0.921″ less than latest Coast Survey.
Early Coast Survey, 1.989″ less than latest Coast Survey.

Various comparisons made throughout the state have shown that the principal triangulation points of the Borden survey are determined probably within 5 to 10 ft. of the position obtained by the latest observations.

The results of the triangulation work as published by Hon. John G. Palfrey, the Secretary of State in 1846, are known as "Palfrey's Tables"; they are prefaced by an introduction and explanation prepared by Mr. Borden and by Mr. Charles O. Boutelle, who was one of Mr. Borden's assistants and afterwards a well-known assistant of the United States Coast and Geodetic Survey, describing the methods of using the information and the necessary tables and formulæ to enable a surveyor to use it without recourse to other books except logarithm tables.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by July 15, 1907, for publication in a subsequent number of the JOURNAL.]

DISCUSSION ON MR. MANSON'S PAPER, "THE STRUGGLE FOR WATER IN THE GREAT CITIES OF THE UNITED STATES"

(Vol. 38, Page 103, March, 1907).

Mr. Desmond FitzGerald. — The part of Mr. Manson's paper in which the writer is particularly interested is that relating to the water supply of the city of San Francisco. Having been employed by that city for a period covering about two years to aid in the study of many of the questions connected with that supply, and having given testimony upon the value of the works of the Spring Valley Water Works, the writer had an excellent opportunity to become familiar with the troubles menacing the city and to admire the high-minded ideas and the plucky fighting qualities displayed by Mr. Manson in defending the best interests of his city. In San Francisco more than in any other community with which the writer is acquainted, the political boss and the corrupt official are both in evidence. What that city needs more than anything else is a few honest men in its government.

In the Sierras, nature has provided an ideal source of water supply, but what with the dog-in-the-manger policy of the government and the active work of private companies and promoters there seems to be a poor chance for the citizens to secure what they really need for their own health and happiness.

In 1903 the writer spent three weeks traveling over the water-shed of the Tuolumne River in company with Mr. C. E. Grunsky, at that time the city engineer of San Francisco; the nature of the water shed and the opportunities for storage were carefully observed. It would be difficult to find a more perfect catchment area. It is composed largely of bare granite which has been scraped smooth by glacial action. Its area is sufficient, and in one of its valleys, the Hetch Hetchy, there is a site for a storage reservoir of enormous capacity which can be developed at comparatively small expense. The great difficulty is the distance from the city, about 150 miles, but when all the advantages and disadvantages are carefully weighed it seems probable that the wisest course for the city to pursue will be to move in that direction and to turn a deaf ear to the many schemes put forward in the interest of promoters. If all the towns and cities within a reasonable distance of San Francisco would unite in forming a Metropolitan District the burden could be more

easily carried. No one who has not studied the variety and complexity of the money interests involved in the water question in San Francisco can really form an idea of the difficulties to be overcome. The people at large seem to have been content to leave the solution of their most important problems to those who are concerned principally in filling their own pockets from the public crib. It is to such men as Mr. Manson that the city is largely indebted for an intelligent appreciation of the real issues in the struggle, and he has happily the courage of a real reformer.

DISCUSSION ON MR. RICHARDS' PAPER, "FIRE PREVENTION APPARATUS" (Vol. 38, Page 196, April, 1907).

A

Mr. R. B. Green. — It is evident that no one system of fire protection can be depended upon to guard against such a general catastrophe as that which led to the San Francisco fire. In the search for all possible emergency aids it would seem that possibly deep trunk sewers might furnish a supply of water for a fire engine's suction when all regular water supplies are crippled. Every manhole would be a possible suction well.

A shock that would cripple a water main under pressure might break a trunk sewer, but would probably not choke it to prevent both ground water from coming down and back-water from backing up from the outlet, unless there should be a tidal wave, such as would cripple even a fire-boat service. Back water often extends in trunk sewers up through the low level business sections of water-front cities, and could be had in new ones by dropping a small portion of the invert below outlet level. A brick intake main extending back through the lower parts of a town would be similar, but more costly. Similarly, sewers in higher districts known to have large inflows of ground water might also furnish a certain amount of aid in extreme emergencies. Bags of sand to dam a small flow or drop-sumps would aid in the smaller sewers.

Gates or temporary dams at the outlet of large sewers would aid in backing their flow up to the higher levels distant from the harbor front. This effect would be aided by having the fire boats pump into the sewers after their outlets were closed.

OBITUARY.

Nelson Spofford.

MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

NELSON SPOFFORD, son of Sewall and Elizabeth Nelson Spofford, of Georgetown, was born in 1826. In the earlier part of his business life he taught school for several years, an experience which doubtless had its effect in the development of his characteristic qualities. He established himself in Haverhill, succeeded his brother-in-law, Captain Nathaniel M. Edwards, in his civil engineering office in 1861, and came into possession of the business and maps of Henry D. Thoreau, the celebrated author, who some years before practiced surveying in Haverhill. The pursuit of that business became his principal life work. He made plans of a large part of the city and became one of the best known of its citizens. Many of the streets of Haverhill were located by Mr. Spofford's advice, and he proposed a street parallel to Merrimac Street and two hundred feet north of it. He continued his activity to the end of his life. Within the last two years he made a preliminary survey for a street railway from Haverhill to Danvers and Salem.

Mr. Spofford's work in the city of Haverhill led to his noticing the imperfection of the marking of its boundary on the New Hampshire line, and he promoted the passage, in 1885, of Acts of the legislatures of Massachusetts and New Hampshire for the re-marking of the line and the setting of monuments. He was appointed one of the commissioners for this work on the part of Massachusetts, but shortly afterward resigned to become their surveyor, and he devoted the greater part of his time for the rest of his life to this work and its continuation along the Vermont boundary of the commonwealth. His thoroughness was such that he had researches made in England to obtain documents, and he exercised his skill in some novel ways in running the lines. He presented some account of the work to the Boston Society of Civil Engineers in December, 1904. He made a gift to the library of the Society of a copy of the valuable report published in 1846 by the commonwealth upon the Borden Survey, containing the tabulated geodetic positions of the points determined.

He was a skillful workman in wood and iron and delighted in ingenious contrivances in his workshop. He was the inventor of the Spofford bit brace for carpenters, which has become known and sold throughout the country, and for several years he received a considerable sum in royalties from that invention. He also invented an equal arc meter for use of engineers. To establish his views on some practical engineering or scientific subject, local history, county, state or national affairs, he was willing to spend money and much time, even to neglecting his business. He was a reader of practical and scientific works. His interest in public affairs continued as long as he lived. He published during the last few years of his life communications to the newspapers upon the boundary question and upon other subjects, as the Panama Canal, fireproof construction and the metric system of weights and measures, to whose adoption he was violently opposed.

He was of domestic tastes, was industrious, abstemious in his habits and was energetic and persevering to an exemplary degree.

He married Lucy A. Edwards, of Haverhill, and two sons, John S. Spofford and Nathaniel Spofford, survive him. He died at Haverhill, October 3, 1906, after an illness of only a few days.

FRED. BROOKS,
RICHARD A. HALE,
Committee.

Editors reprinting articles from this Journal are requested to credit the author, the Journal of the Association, and the Society before which such articles were read.

Association of Engineering Societies.

Organized 1881.

Vol. XXXVIII. JUNE, 1907. No. 6.

THE DIVERSION OF THE COLORADO RIVER INTO THE SALTON SINK AND THE EFFORTS MADE TO RESTORE IT TO ITS FORMER CHANNEL.

By J. A. Ockerson, Member of the Engineers' Club of St. Louis.

[Read before the Club, February 20, 1907.]

None of the physical features of our country has attracted such widespread attention during the past year as the Salton Sea and the Colorado River. Frequent articles have appeared in magazines and newspapers describing more or less accurately the existing conditions, the cause of the Colorado break, and the effect thereof. Many of them are grossly exaggerated as to the ultimate size of the so-called sea and its possible effect on the climate.

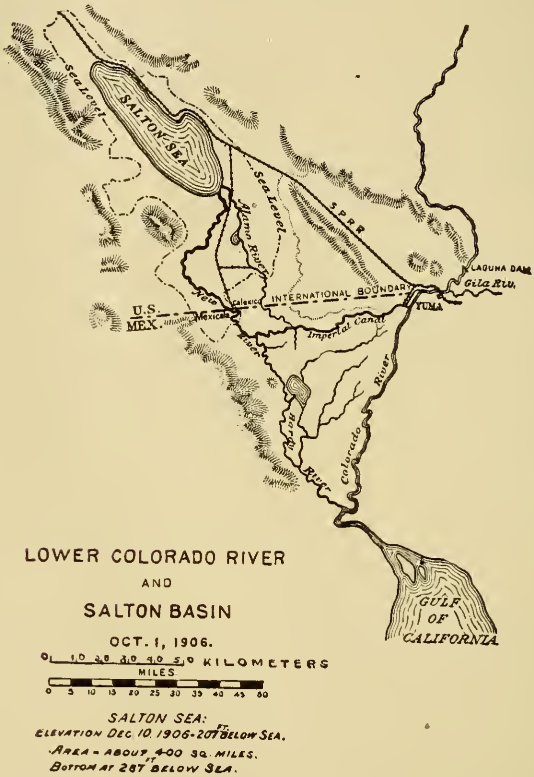
The writer visited the break in August, 1906, just before the active work of closure was begun by the Southern Pacific Railway Company, and again in December of the same year, shortly after the work had failed.

The Gulf of California many centuries ago extended in a northwesterly direction some 150 miles from its present northern terminus. The mouth of the Colorado River was then about 120 miles from the extreme northerly end of the Gulf, and its sediment-laden waters formed a delta which finally extended across the salt water and cut off a portion thereof, which later became the Salton Sink, now more generally called the Imperial Valley.

The river reached the gulf with a slope of over 2 ft. to the mile and readily built up a barrier clear across to the foot hills of the Cocopah range of mountains, and then followed the eastern slope as its main outlet. This delta ranges in height

from 130 ft. above sea level at the United States — Mexican boundary line to something over 20 ft. above sea level on the western side of the gulf basin. The normal slope to the gulf is now about 1.7 ft. per mile in a distance of about 75 miles. A mesa extending from the hills at Yuma downstream limits the flow to the eastward.

The waters of the northern portion of the gulf, which were cut off by the delta deposits, evaporated in the course of time



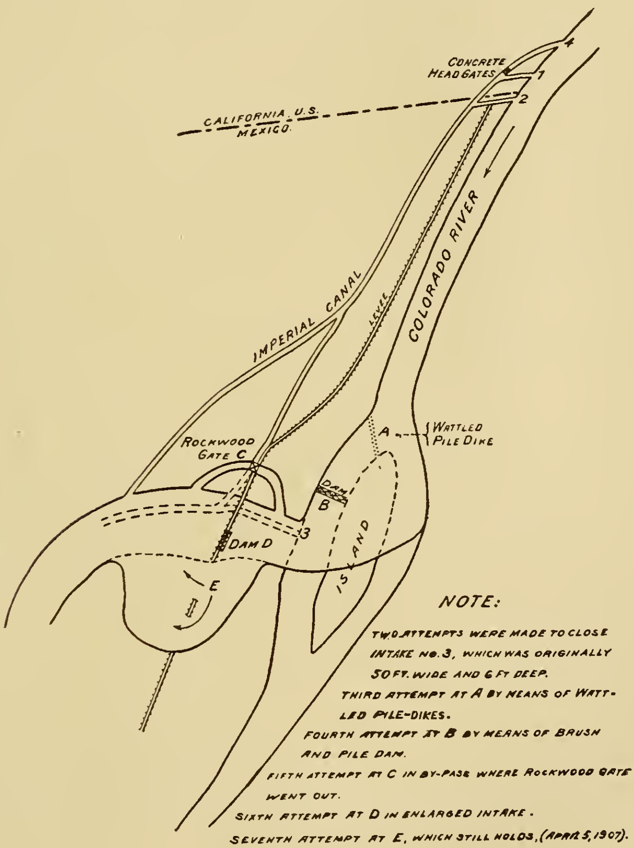
and the basin became dry, leaving extensive deposits of salt. The bottom of this basin is 287 ft. below sea level.

The Southern Pacific Railway, after crossing the Colorado River at Yuma, reached the edge of the sink some 60 miles to the westward, and there its comparatively smooth surface was so attractive that the road follows it for a distance of about 75 miles.

Without water, this vast plain, with an area of about 4 000 sq. miles, was a torrid desert, divided between the United States and Mexico.

The alluvial deposits of the Colorado are of great depth and undoubted fertility when supplied with sufficient water to nourish growing crops. It was natural, therefore, that some means of irrigation should be sought, and the Colorado River was the natural source of supply.

The boundary line between the United States and Mexico is so situated that water taken from the river north of the line



must be carried southward into Mexico around the base of a sandy mesa and then across the line again to the California lands north of the boundary line.

As early as 1893 a company was formed, known as the Colorado River Irrigation Company, to irrigate what was then known as the Colorado desert and now known as the Imperial Valley in southern California. Their work proved a failure, and they were succeeded by the California Development Company, which is responsible for the present trouble.

This company began work by tapping the river on the right bank just above the boundary line, and carried the water through a canal, following the route heretofore indicated.

In order to establish their rights in Mexico and secure certain privileges therefrom, an auxiliary company was organized with a Mexican charter, having essentially the same directorate as the American company.

By 1903 the Imperial Valley had acquired such a population that the supply of water was not sufficient, and the canals were so badly located as to slope that they silted up very rapidly, the machinery owned by the company being inadequate to keep them open. They then opened a second intake just below the boundary line and leading directly back to the canal. This still proved to be inadequate, and they obtained a concession to take 10 000 cu. ft. of water per second from the river in Mexico. At the beginning of the hot season of 1904 the lack of water became so serious in the valley that it was decided to cut a third intake at a point 4 miles below the boundary line. This intake, No. 3, was located behind an island which divided the river into two channels. The cut was about 50 ft. wide and about 6 ft. deep, and led directly back to the canal. It was completed in October, 1904. No head gates or controlling works were provided, owing, it is now said, to lack of funds. Even this intake silted up at low water and had to be dredged out, but the floods in the fall of 1904 started active erosion, and by the middle of December the water found its way to Salton Sink, via the New River, and thus began the present Salton Sea.

By the spring of 1905 the width had increased to 100 ft. and the depth to 20 ft., and it was deemed best to close it. The plan adopted was to drive piling across the channel near the river and fill in between the rows of piles with willows and bags of sand used as ballast. No effort was made to secure the approaches, and the structure failed shortly after its completion, on the approach of a moderate rise in the river. This work is described as technically successful.

Then one of the subsidiary water companies of the Imperial Valley offered to undertake the closing of the break, and they began operations about June 1, 1905. Their plan provided two rows of piling 15 ft. apart, to be filled in with brush and sand bags. They also failed to see the importance of protecting the approaches, and as their work advanced from one side the erosion of the opposite bank readily kept pace therewith, and the work was finally abandoned.

By this time sufficient water had reached Salton Sea to encroach on the Southern Pacific Railway, and necessitated moving portions of the track.

After the summer floods of 1905 had passed, a different plan was decided upon, and a third attempt was made to check the flow. This time a single-row pile dike wattled with brush was to be extended from the head of the island lying opposite to the intake to the right bank, the object being to silt up the channel on the west side of the island which carrried about two thirds of the total flow of the river. But the bottom rapidly eroded and undermined the piles, and another row of piles was started farther up the stream, with like results, and the work was again abandoned.

A fourth attempt was then made by a San Francisco contractor, in the construction of a pile and brush dam some 600 ft. long, to close the channel west of the island. The plans contemplated a mattress foundation for this dam. About a month after the dam was begun a flood from the Gila River destroyed the work and washed away the head of the island to a point considerably below the site of the dam, and the fourth attempt was added to the list of failures.

In the meantime a wooden A-frame head-gate was designed and located near the north bank of intake No. 3, which was now the main river, for the purpose of diverting the low-water flow through a by-pass and controlling the same by means of a gate. The structure was of ample capacity to pass the normal low-water flow, which would leave the work of closing the intake proper to be handled on dry ground, and on the completion of that work the gates were to be closed and the river would then be diverted to its old bed, which had become dry, as the entire volume now flowed to the Salton Sea.

This gate was known as the Rockwood gate. It was supported by some five hundred piles crossing the by-pass, which was 200 ft. wide. There were three lines of sheet piling and the bottom was covered with a plank floor 60 ft. in width. There were 40 openings, each 4 ft. in width, and the flow was controlled by means of flashboards. The construction of this gate was still in progress when the spring floods of 1906 put a stop to the work. The intake by this time had enlarged to a width of about 1 800 ft., and the erosion of its southern bank left the head-gate some 1 500 ft. inland, thus materially increasing the length of the by-pass required.

It may be well to say here that in handling this problem of

closure it was necessary to insure to the people of Imperial Valley a sufficient supply of water for their needs. So a complete closure would be as fatal on the one hand as an overflow on the other. Up to the present time they have had to face only the latter.

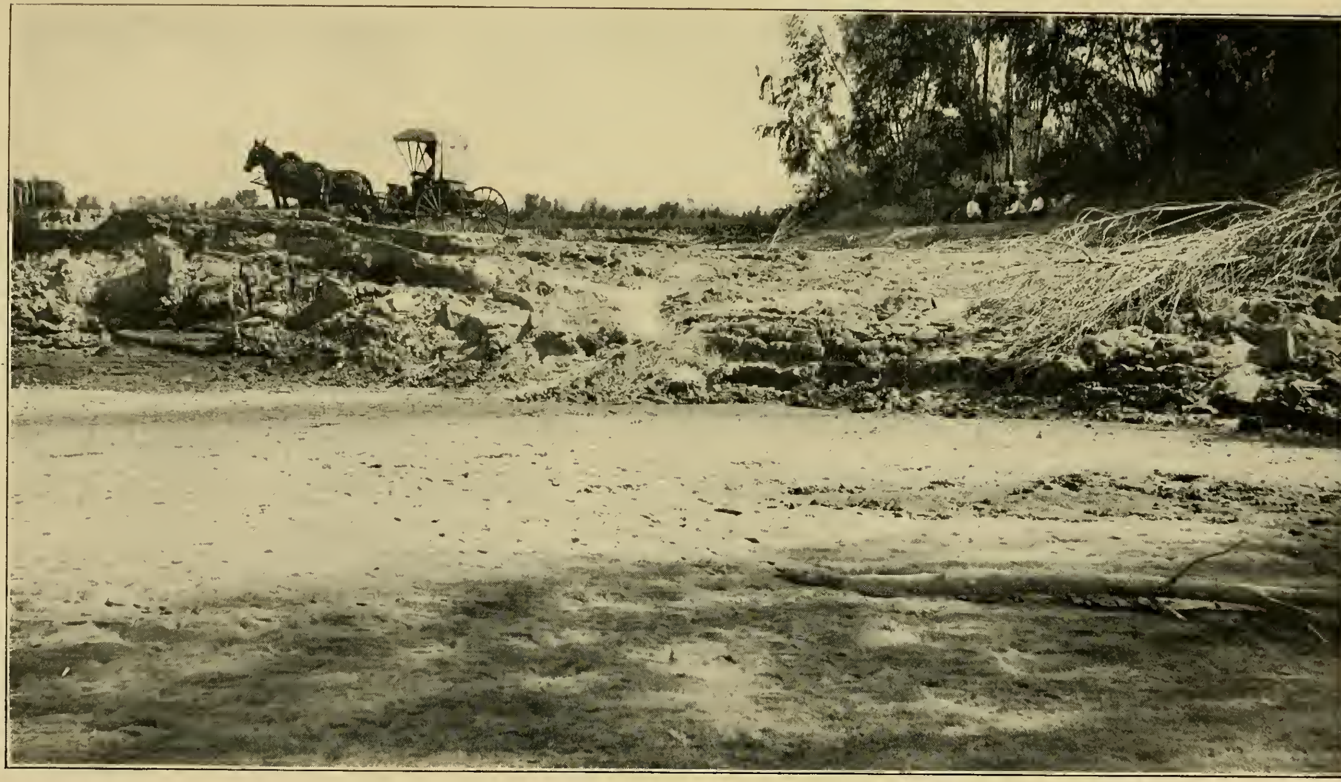
By this time it became apparent that permanent head-gates were essential to the success of the irrigation project, and such gates were designed and constructed a short distance north of the boundary line. This structure is made of reinforced concrete and has 11 gates of the Taintor type, 12 ft. wide and 10 ft. high. There is also a by-pass gate for skiffs and like craft. The capacity of these gates was estimated at 10 000 cu. ft. per second. One end and a portion of the base are founded on the solid rock. The river end terminates in the alluvial soil. Weight is added to the structure by filling the hollow spaces with gravel.

During the short interval these gates were in operation last November they silted up and filled with drift to such an extent as to threaten their usefulness.

The spring and summer floods of 1906 were unusually prolonged, and from March to June the break on intake No. 3 had widened from 500 ft. to 2 600 ft., and the surface of Salton Sea rose about 40 ft., which necessitated the rebuilding of about 40 miles of the main line of the Southern Pacific Railway, and a considerable portion of the Imperial Valley branch was badly damaged by being washed out.

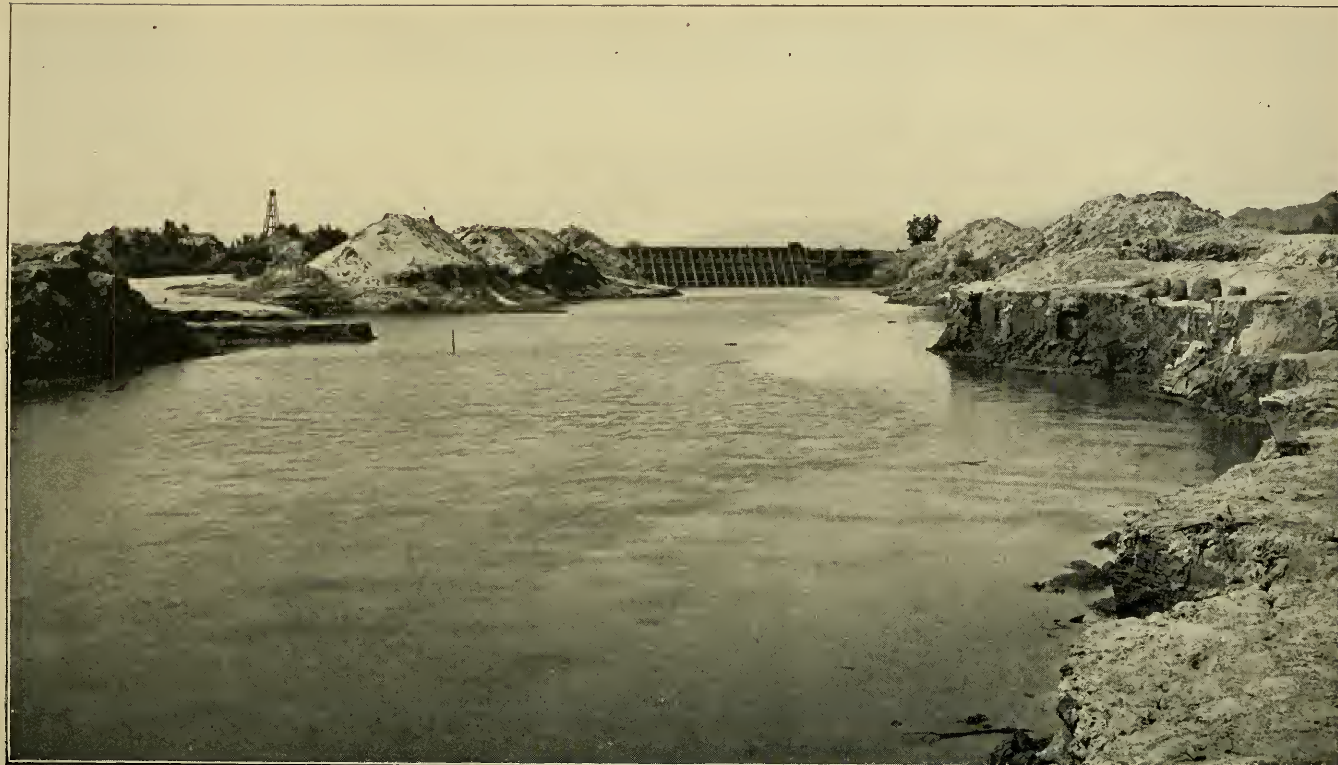
At this juncture the Southern Pacific management assumed charge of the work of closing the break, and the fifth attempt was begun in August, 1906. The plan this time was to build a solid dam entirely across the break, opening a by-pass so as to carry the low-water flow through the Rockwood gate. Some 2 000 ft. of the dry portion of the bed was simply an earthen embankment.

The flowing channel, 600 ft. in width, was cut off by a rock-fill dam on a mattress foundation 100 ft. wide and about 18 in. thick. A trestle carried a track across at such height as to permit of dumping material from the cars to the maximum elevation required. The equipment of the Southern Pacific Railway was drawn upon to a lavish extent, and the material, gravel and rock was filled in with great rapidity and in enormous quantities. All accessible quarries within 400 miles contributed stone, gotten out by an army of men. Hundreds of teams and more than a thousand men were engaged in the immediate vicinity of the dam, and the work was certainly rushed in an admirable manner.

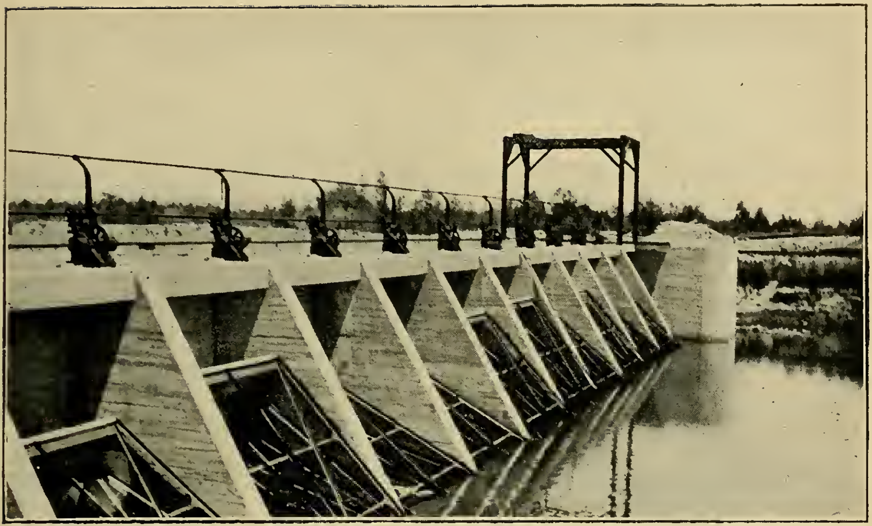


Buggy standing in the old bed of the Colorado River. The new bed in foreground shows at that point the extent of the depression of the new bed due to flow into Salton Sea.

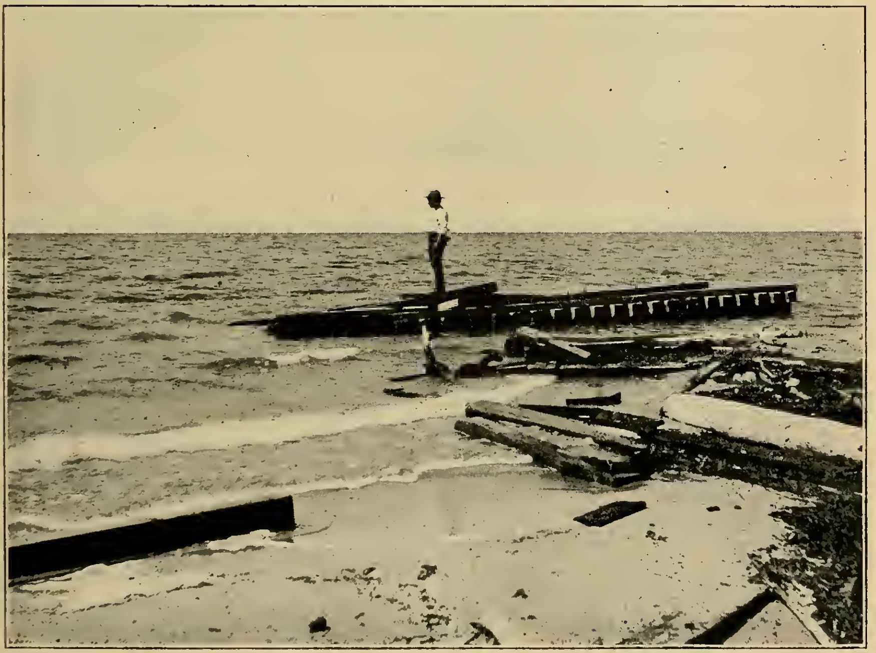
PLATE 2.



The Rockwood Head-Gate which was intended to control flow of Colorado River while the break was in process of closure. It failed at the critical moment and floated down stream. Taken August 26, 1906.

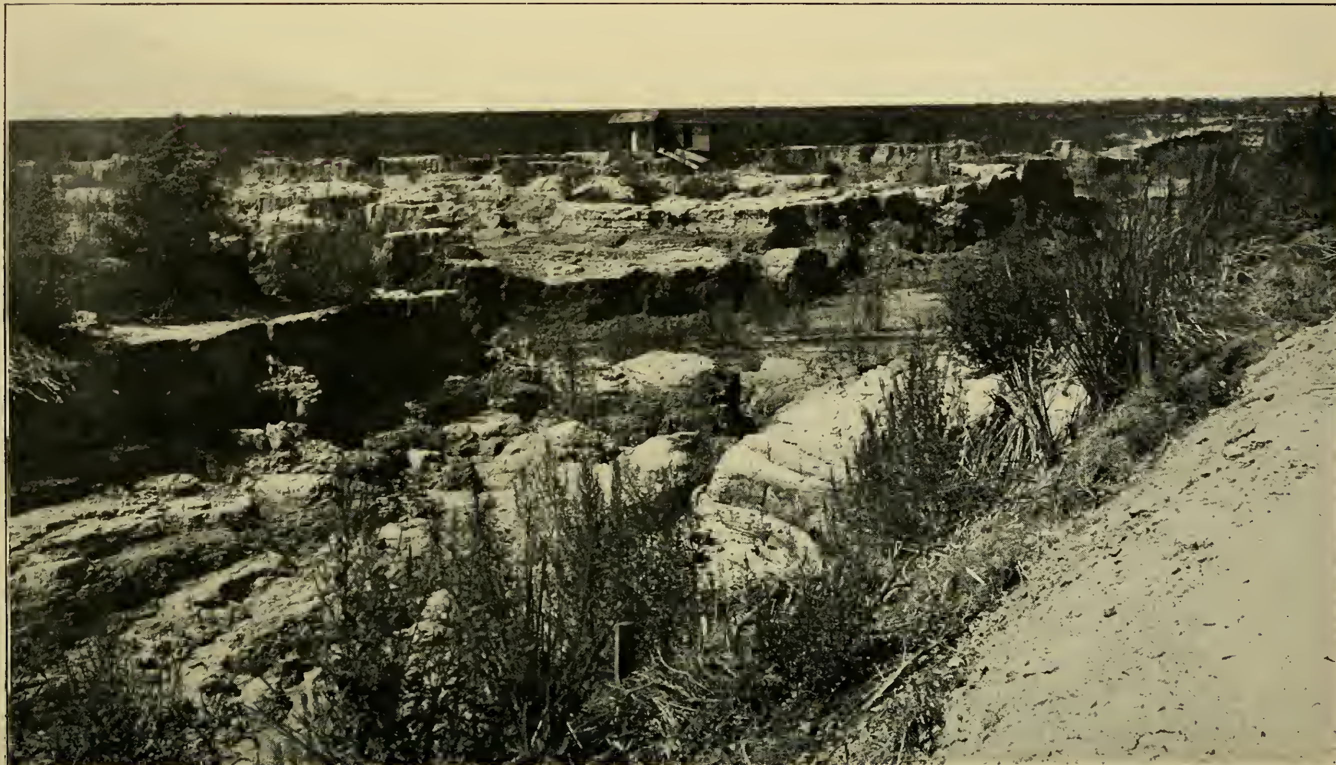


Concrete Head-Gates (Taintor Gates), Imperial Valley Canal.



Salton Sea: Part of Abandoned Track of Southern Pacific Railway. This point is 205 feet below sea level. Depot near by was moved three times to keep it above advancing flood. Taken August 26, 1906.

PLATE 4.



View showing the extraordinary amount of erosion of the surface of the ground in Imperial Valley caused by the water rushing through the Colorado River break toward Salton Sea.

Rock and gravel were dumped in until the water level was raised about 6 ft. on the upper side of the dam, and the whole flow was then diverted to the by-pass through the Rockwood gate. Success seemed assured, but a slight rise in the river, accompanied by drift, choked up the gate, and erosion of the by-pass, for which no protection had been provided, became alarmingly active and an effort was made to check it by dumping in rock above the gate. While this was going on, about 120 ft. of the gate suddenly rose up and floated off, and in a short time the river was again free from control, and continued on its way to the Salton Sea without hindrance. This was wholly unexpected, and those in charge who had been so confident of good results were now thoroughly discouraged.

The channel across which the dam was partially completed was dry, and the problem of closure was transferred to the by-pass.

There was no time for delay, and the sixth attempt to divert the river was promptly inaugurated. The entire force was turned toward the closure of the by-pass by means of three parallel rock-fill dams, each sustaining a portion of the head. These were raised gradually until the water was finally shut out and diverted over the dam proper. Then, with an extraordinary burst of energy, the entire line was raised, and on the 4th day of November, 1906, the water began flowing down the old bed of the river toward the Gulf of California, and twenty days later the closure was complete.

While this work was in progress a tremendous amount of material was handled and a shortage of cars on that work at least was unheard of. Over two hundred carloads of stone per day was no unusual amount to handle. The rock came on flat cars and the blocks were sometimes too large to move by hand, and they were then broken up with dynamite as they lay on the cars.

The concrete head-gates were put into commission, and Imperial Valley was supplied with water again under control. Levees were completed from the upper head works down to the dam and below the same for a considerable distance in order to prevent the floods from overtopping the natural banks of the river.

The sixth attempt at closure was apparently successful, and great rejoicing prevailed among the people of Imperial Valley whose fate had been trembling in the balance for more than two years. The newspapers at the time announced in bold

headlines, " Long period of suspense is over. Closure of break in river effected. The only thing the people of the Imperial Valley now have to worry about is the fact that they have nothing to worry about."

But they were again doomed to disappointment. In less than a month the river had once more abandoned its old bed for the more attractive route to the Salton Sea.

The closure works were still regarded as technically successful, because the new break occurred at a point some 1 200 ft. south of the end of the dam; the results, however, were far from satisfactory to the people of Imperial Valley.

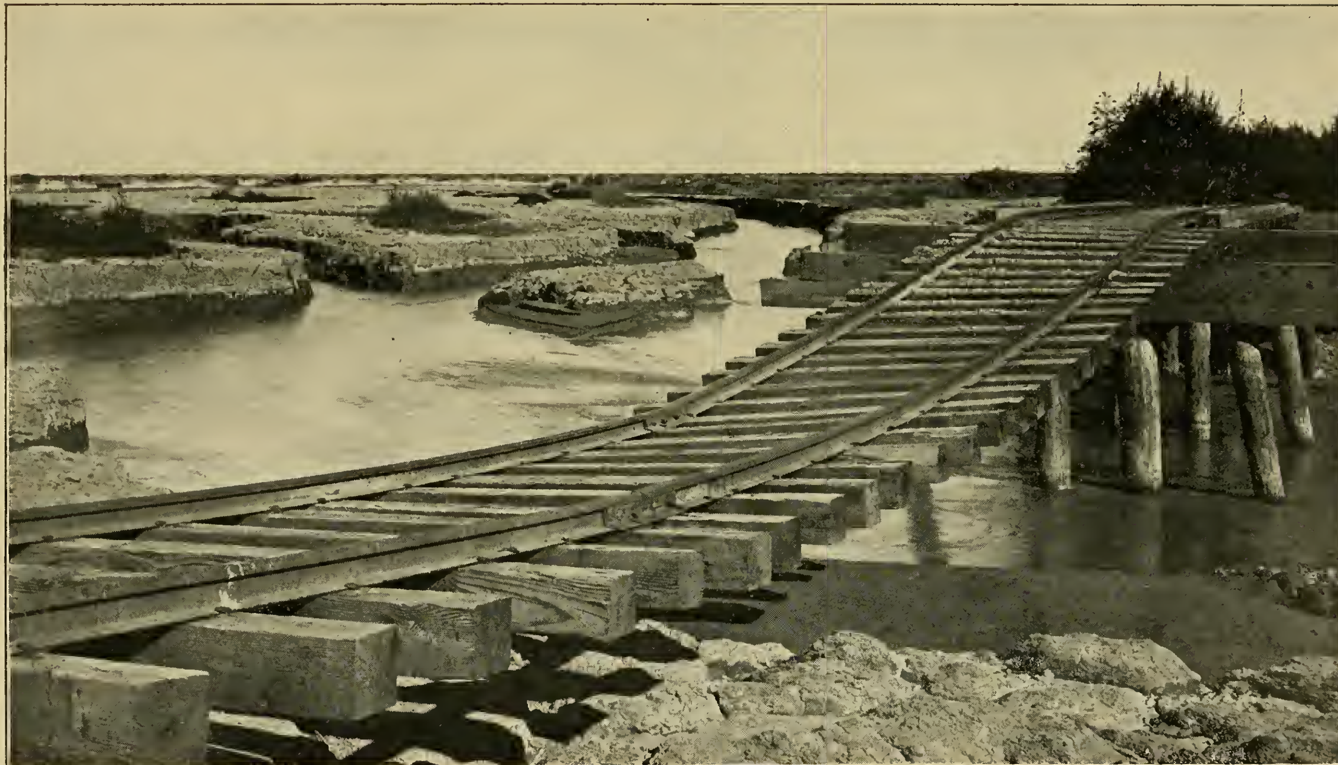
The last break was clearly attributable to defective levee construction. With water only about 1 ft. above the natural surface of the ground, several leaks developed through the natural soil, which gave way beneath the levee, and before means could be taken to stop it, earth and levee crumbled, and again the river broke away fom its captors and resumed its work of filling up Salton Sea.

As a foundation for a levee the soil is extremely treacherous, being porous and filled with cracks, roots and drift. In spite of this fact, even the ordinary precautions used in levee building with far better material were wholly neglected. One glaring defect was that of having the borrow pit on the land side of the levee. Under such conditions, failure was more than probable.

It is said that over two million dollars had been expended up to this time in the various attempts to divert the Colorado River to its former bed. A vast amount of damage had been done in Imperial Valley to the towns, farms and homes of the inhabitants. The Southern Pacific Railway suffered great loss in the submergence of its tracks. Some 8 000 to 10 000 people in the Valley were in distress, sadly discouraged and helpless. An appeal was made to the general government, which was promptly responded to by our worthy President, who, in a message to Congress, urged the passage of a measure providing funds for making a permanent closure of the break.

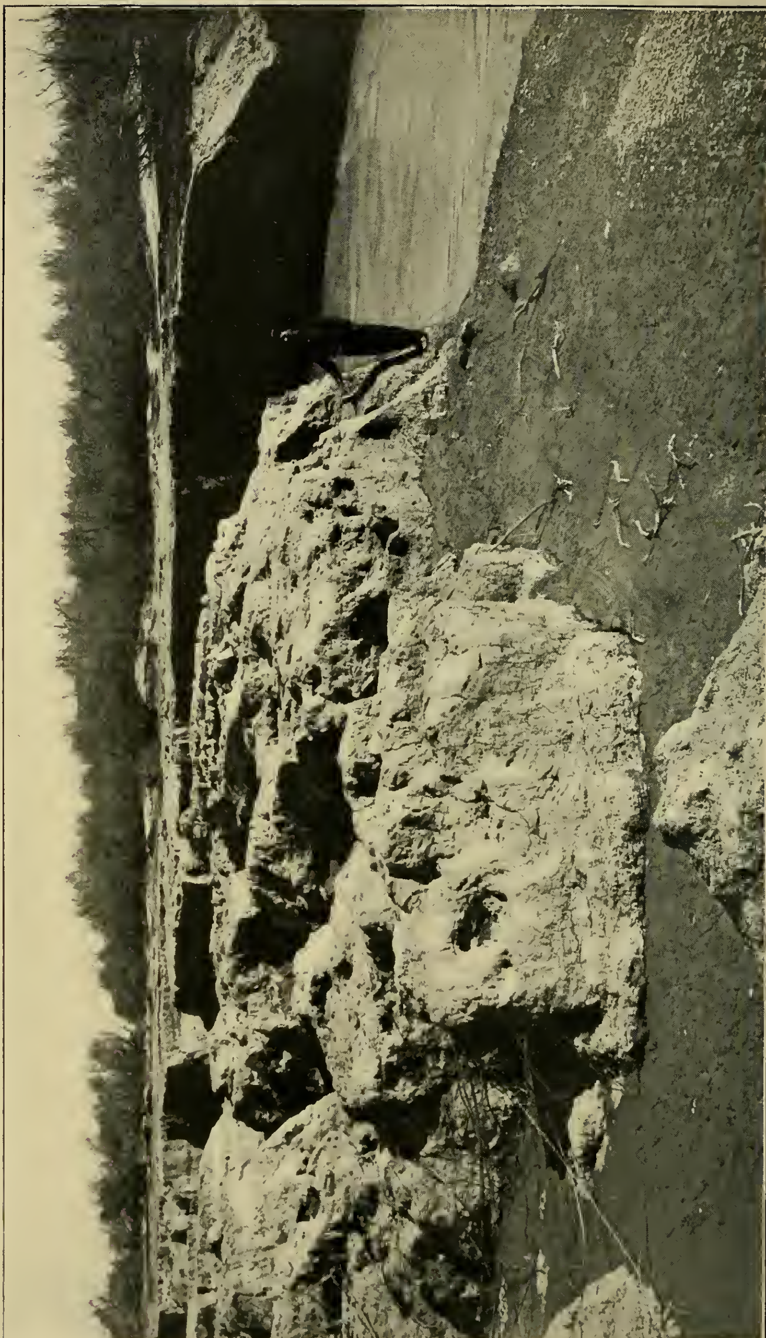
In the meantime but a very short period of the low-water season remained in which to complete another closure, and the organization, equipment and the credit of the Southern Pacific Railway again came to the rescue, and the seventh attempt to turn the Colorado River through its old channel to the Gulf of California was promptly begun.

The work was done under many difficulties. Unexpected floods, ranging in volume from 30 000 to 50 000 cu. ft. per sec-



View showing how surface of ground in Imperial Valley was washed into gullies by Colorado River water rushing toward Salton Sea. Taken September 1, 1906.

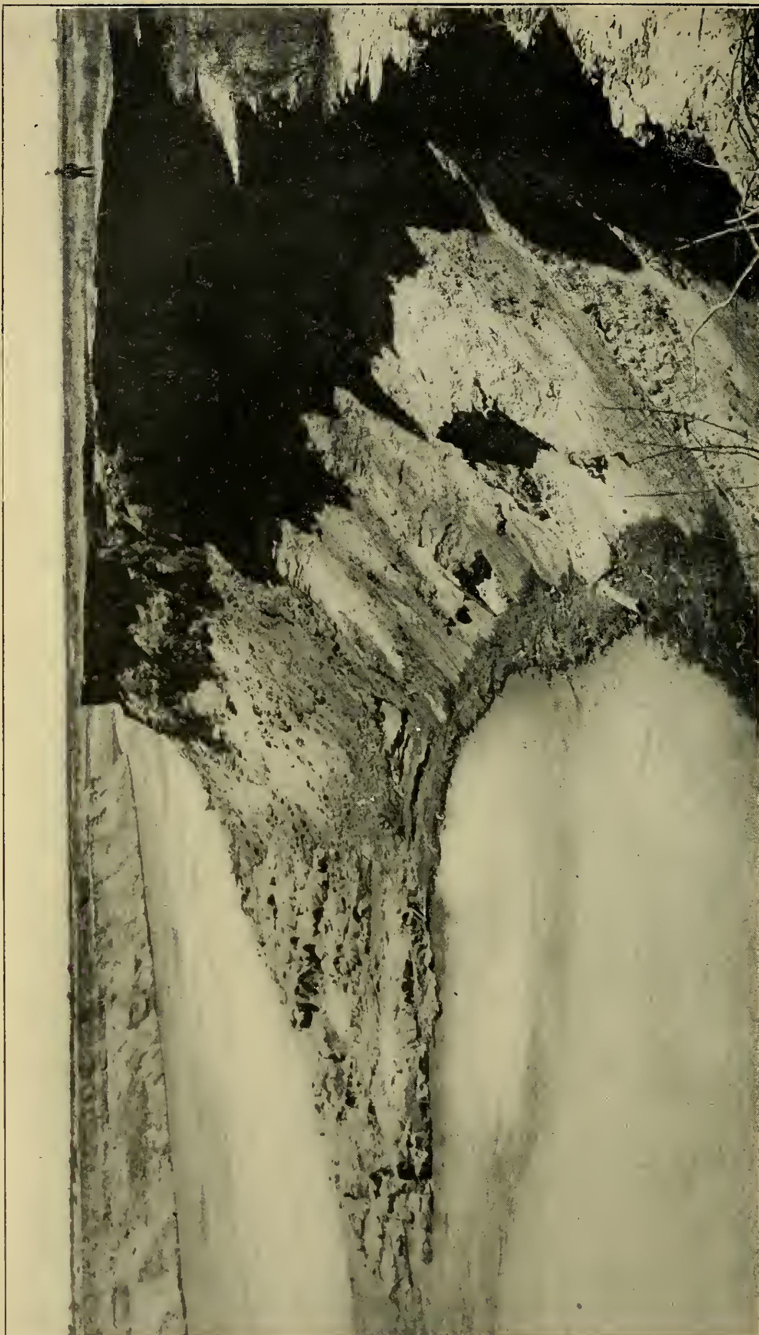
PLATE 6.



This view shows the head of channel formed by gathering of numerous small streams from the Colorado River break, all on their way toward Salton Sea. Also shows how the surface of the ground was eroded by the rushing water.

View showing banks of New River, 4½ miles northwest from Brawley, Cal. Banks caving away very rapidly. Taken August 30, 1906.

PLATE 8.



View showing erosion of the banks of New River in Imperial Valley, due to the Colorado River break and water flowing to Salton Sea.

ond, demolished the trestle four different times, but the lower trestle was finally completed and a second trestle was constructed across the break about 50 ft. above it. Active dumping of material from the lower trestle was then begun, and in 14 days and 6 hr. a rock-fill dam was completed, and the Colorado River, on February 11, 1907, was again flowing seaward through its old channel, and the intake route to Salton Sea became practically dry.

In the first twelve hours of the work 7 000 cu. yd. of heavy rock was placed in the dam, and a total of 2 200 carloads of material was required to complete it. No foundation mat was used, reliance being placed in the ability to dump material so fast that the settlement would not materially retard the completion of the work. The dam sustained a head of some 13 ft. before the flow was diverted to the old channel, the bed of which was much higher than the bed of the intake, owing to the depression of the latter channel due to the greatly increased slope to the Salton Sink. The volume of flow during the progress of the work ranged from 15 000 to 20 000 cu. ft. per second.

The reconstruction of the levees, to eliminate the defects developed by the previous break, was also actively carried on, and it is hoped that the work done may successfully resist the spring floods.

As an emergency work, the situation has been handled in a masterly manner, regardless of cost, by the management of the Southern Pacific Railway and its engineers. It is evident, however, that a properly developed scheme for the irrigation of the Imperial Valley in the beginning would, in all probability, have obviated the necessity for such a tremendous waste of energy and money.

The Colorado River has a watershed covering an area of 225 000 sq. miles, and the discharge at Yuma ranges from 3 500 cu. ft. per second at extremely low water, to 200 000 cu. ft. per second at maximum stages. Immediately above the break, normal slope of the river is about 1 ft. per mile.

The water at the break leaves the river at an elevation of 130 ft. above sea level, and when the flow to Salton Sink began it had a fall of over 400 ft. in a distance of about 90 miles. Flowing as it did over very loose, fine, alluvial soil with such an excessive slope, it first created havoc with the surface of the ground before gathering into defined channels, and then developed great chasms. In one case the gorge was eroded to a depth of 80 ft. and 1 300 ft. in width, with a vertical cataract

that moved upstream at a maximum rate of nearly 4 600 ft. in a day. This cataract was the most alarming feature of the whole situation, as it was realized that if it should once reach the bed of the Colorado River proper, a diversion of that stream to its former bed would be practically out of the question. It would also move very rapidly upstream to the Laguna Dam, under construction by the government, and it would be quickly destroyed. The Imperial Valley would be rendered uninhabitable, both on account of its gradual submergence by the filling up of Salton Sea and the difficulty of securing water for irrigation purposes from the depths of the gorge, far below the surface of the lands.

The Southern Pacific Railway would be forced to construct, at great cost, about 80 miles of new track through the rugged foot hills.

Leaving out the value of the annual production of the valley for future years, the loss incident to the Colorado break, if not brought under control, has been estimated at a hundred million dollars.

There are advocates who recommend that this destruction should be permitted to go on, in order that a great lake may be formed, which, it is claimed, would increase the rainfall of the surrounding country for a distance of several hundred miles. The legislators of Utah and Texas, with this in view, petitioned Congress to allow the basin to fill up.

In order to show that these ideas are wholly erroneous, it is only necessary to call attention to the fact that the Gulf of California, similarly situated, and many times the area of the Salton Sea, is only about a hundred miles distant.

From the best obtainable data it appears that the evaporation from a reservoir in that climate amounts to about 7 ft. per annum. Salton Sea might reach an ultimate area of something less than 1 900 sq. miles if the river continued to flow into it. People in Texas and Indian Territory, 800 miles away, claim to be feeling the beneficial effects of added rainfall already. The area at the present time is something like 400 sq. miles, and the normal evaporation therefrom would give an average of 1 ft. of rainfall per annum over an area of about 2 800 sq. miles. Unless there is some special attraction in the localities named, it does not seem probable that any portion of the water evaporated from the Salton Sea ever reaches them. If it does, then the Gulf of California, which is even nearer, should provide an ample rainfall at all times.

One writer suggests that the filling of the basin should be allowed to go on, and even be hastened by cutting a channel from the Gulf of California, in order that it might be used for purposes of navigation, and also exercise a beneficial influence on the arid regions of the United States.

If allowed to flow, the area of the sea would reach about 1 900 sq. miles in something like fifty years' time. At that stage the annual evaporation would practically equal the annual discharge of the Colorado River, and the surface would never become high enough to flow over the barrier into the Gulf of California unless the deposits of the Colorado should build up a new delta of such proportions as to change the direction of the flow. The annual volume of sediment brought down by the Colorado River is estimated at over 50 000 000 cu. yd.

With the supply of water cut off by the closure of the break, the water now in the Salton Sea will evaporate in about ten or twelve years.

I am greatly indebted to Mr. H. T. Cory, in local charge of the closure work, and the engineers of the United States Reclamation Service for courtesies extended during my visits and for data furnished me at later date.

[Note. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by September 1, 1907, for publication in a subsequent number of the Journal.]

THE HARVEY CANAL AND LOCK.

By Gervais Lombard, Member of the Louisiana Engineering Society.

[Read before the Society, October 9, 1905.]

Some ninety years ago, Mr. N. N. Destrehan, a wealthy planter living on the banks of the Mississippi River, just opposite the city of New Orleans, carried out what at that time was considered a gigantic undertaking. He dug what he intended for a drainage canal beginning at a point opposite New Orleans adjacent to the Mississippi River, but separated therefrom by the river's right bank and extending about five miles southerly to deep water in Bayou Barataria. This canal was dug by hand, Mr. Destrehan employing several scores of slaves to do the work. As the slaves were only employed on the canal work when not otherwise busy with the plantation work, several years were required to complete it.

At first this canal was dug only 12 ft. wide, and the grade of the bottom was but 3 ft. below mean gulf level. From time to time it was slightly enlarged, as it was found that it could be used as a navigation canal; and the story goes that Lafitte, the pirate, often made use of this canal. Most of the transportation then was in luggers and boats of light draft, and a vast area was reached by means of this canal via Bayou Barataria with its multitude of ramified waterways.

In the year 1858 the canal was dredged to a width of 60 ft. by the Harveys, who had inherited the property. At first the chief traffic was in oysters and the fishery industries; but the time came when cypress timber and agricultural products from the higher banks of Bayou Barataria, Bayou Lafourche and the other streams grew to such proportions that it was decided to connect the canal directly with the Mississippi River by means of a lock.

So in 1882 work was commenced on the lock, which was completed within a year. However, it was found, when this lock was tested, that it failed to hold a head of even 14 ft. It was believed at that time that the failure of the lock was due to faulty construction and the use of inferior cement in the masonry. The brick masonry settled and cracked, and the water went under the flooring of the gates, threatening disaster

from overflow when the Mississippi River was at flood stage. The lock was promptly condemned by the levee and railroad authorities, and the canal was dammed across its mouth with an earthen dike. The canal proper, however, was enlarged to a width of between 50 and 60 ft. for its entire length, and is still used by sailboats, steam and motor craft for bringing rafts, fish and produce to the banks of the river, where the cargoes are transferred over the levee to boats in the river, or hauled by wagons, which are ferried across to the city of New Orleans.

In the meantime, Company Canal, which was excavated about the year 1830, and which is located several miles above Harvey, leading from the river at Westwego back to this same system of waterways, had been successfully locked, connecting it with the Mississippi River. In 1902, the Harvey interests were incorporated into a stock company, known as the Harvey Canal Land and Improvement Company, and the lock project again undertaken, as it was found that ample business was in store for both canal companies. A contract was let to enlarge the canal for two miles nearest the river to a width of 80 ft. and to a depth of 7 ft. below lowest canal level. This gave ample room to handle the large rafts being brought to the Louisiana Cypress Lumber Company without interfering with the vessels.

Mr. R. E. DeBuys, a member of the Louisiana Engineering Society, was retained as engineer in charge, and he designed the new lock. The location was fixed by the canal company adjacent to and immediately in the rear of the original lock, no part of which was to be used in the new lock. Only two test borings were made, one near each gate. The information thus gleaned showed that where the front gate was to be located there was nothing but fine gray sand (quicksand) for a depth of 81 ft. below the natural surface of the ground, with the exception of one or two streaks of sand mixed with blue clay, the nearest of which was 38 ft. below the floor of the gate. Notwithstanding this fact, the company directed the work to proceed on the location already selected by it. The boring near the rear gate location showed a thick stratum of hard blue clay for a depth of 63 ft. before quicksand was encountered.

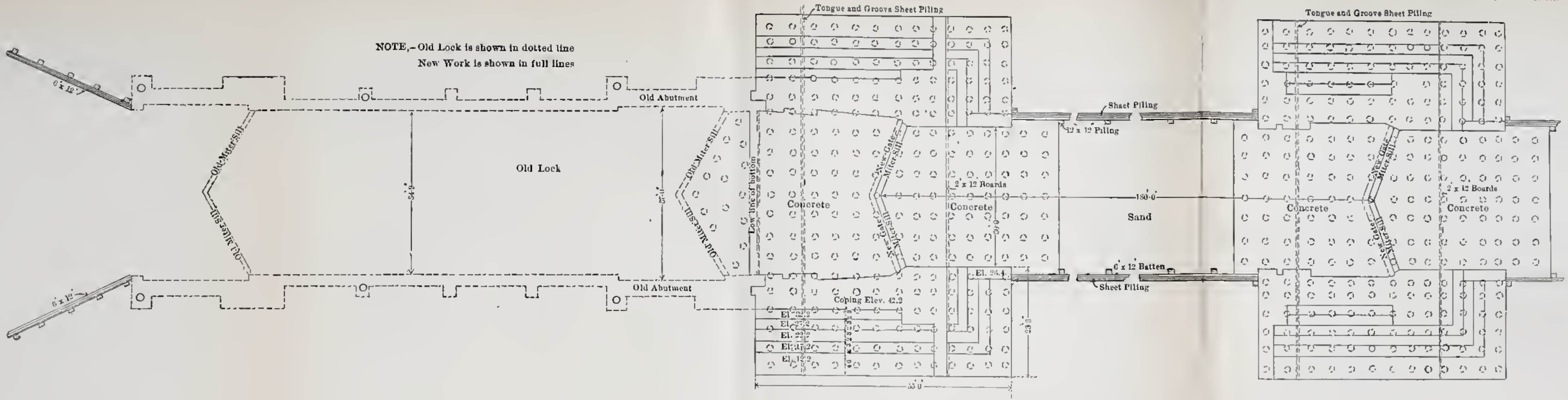
As will be seen from the plan, the old masonry lock chamber and gate abutments serve as a forebay approach to the new lock. There could be no salvage from the old lock, as the gates, though steel, were badly corroded by rust, and had been designed to stand a fluctuation of only 12 to 14 ft. in the river,

while, owing to new conditions, a head of 19 to 22 ft. had to be provided for at this time. The water surface in the canal varies but little comparatively and remains within a few inches of mean gulf level, seldom fluctuating more than 3 ft., due to tides in the gulf, except in times of overflow, when crevasses occur in the levee line on the banks of the Mississippi River above or below the site of the lock. The river, however, has a fluctuation at this point of about 19 ft. from the lowest to the highest water mark, and it is estimated that when all the outlets to the Mississippi River have been closed and the levee line held all the way on both sides, at least another foot of water may be expected.

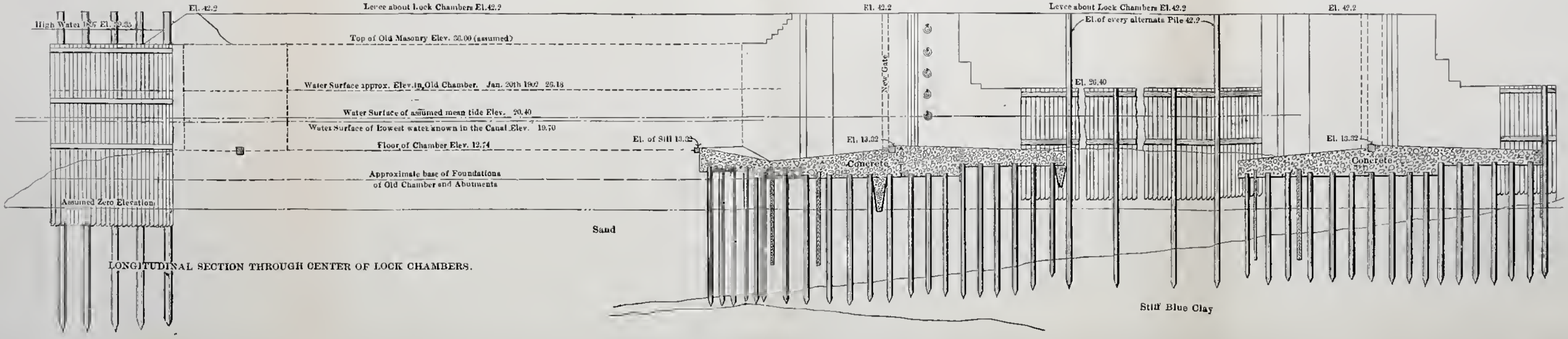
The sills of the old gate were eight (8) ft. below ordinary canal level, and, as the old lock had a clear width of 34 ft. 9 in., while the new lock is only to have a width of 30 ft. 6 in., said old lock was not wrecked or cleared away, but left, as stated above, to serve as an approach. The miter sill of the new front gate is 7 ft. below ordinary canal tide, and the sill of the new rear gate is 1 ft. lower. The reason for elevating the front sill was that for the greater part of the year there is a head of more than 1 ft. from the river and that the deeper draft boats which could just pass over the rear sill could almost always be floated over the front sill.

As is the case in all this region, no bed rock was within reach, so reliance had to be placed on piling. Round piles, 45 ft. long and not less than 15 in. in diameter at the butt end, and not less than 8 in. in diameter at the blossom end, were used. These piles were spaced 4 ft. centers generally, with closer spacing under the quoin posts and heavier portions of the lock.

When the writer was retained as engineer in charge, vice Mr. De Buys, who could no longer act in that capacity, due to press of his architectural work, to which he desired to devote his entire time and attention, the pile foundation for the front gate had been practically completed, and most of the sheet piles were already driven. The work was being done by the company itself, with Mr. Louis Lesassier as superintendent. This arrangement had been determined upon after sealed proposals had been received and all rejected as too high. The only changes made in the plans after the writer assumed charge were minor and consisted chiefly in additional precautions to prevent the water from displacing the earth beneath the floor of the lock and around the abutments. The transverse rows of sheet piling were lengthened to 25 ft., and two cores of concrete were placed



PLAN OF LOCKS



LONGITUDINAL SECTION THROUGH CENTER OF LOCK CHAMBERS.

beneath as shown on the section. This was done to prevent the water from having a straight flow along the underside of the flooring in case any should get through the sheet piles. Similar concrete offsets were also placed on the vertical land faces of the abutments so as to insure a safer bond between the concrete blocks and the earthwork forming the levee. Reverting to the foundations, after the round piles had been driven and the cofferdam built (a row of triple lap wooden sheet piling entirely around the group), the earth was excavated to a depth of 1 ft. below the cut-off grade of the round piles. To the heads of these round piles were driftbolted and strapped 12 in. by 12 in. caps, transversely, some of which extended clear across the floor and under the heavy abutments or walls. Concrete, consisting of one part Illinois steel Puzzolan cement to three parts of sharp sand and five parts of washed gravel, and reinforced with corrugated steel bars, was then filled in to the top of the caps, thus giving a solid floor 2 ft. thick. The span is 30 ft. 6 in. in the clear between walls, and for that width the floor was sheathed with a double thickness of 3- and 4-in. pine boards laid on the oblique and spiked to the caps. The miter sills, of course, were not only bolted to the heads of the piles they rested upon, but were married into the concrete flooring. Fifteen-inch by 18-in. white oak sills were sought, but not being available, a good quality of long-leaf yellow pine was substituted. The ends of the miter sills extend several feet under the concrete walls, and the faces with which the steel gates are to be in contact, when closed, were sheathed with a strip of steel 6 in. by $\frac{5}{8}$ in. The spread at the foot of the walls is 20 to 23.5 ft., and the width of the walls is narrowed by offsets until they are but 6.5 to 12 ft. wide at the top.

Each gate is, therefore, swung on a concrete monolith containing nearly 1 200 cu. yd. Steel Puzzolan cement was used for all that portion of the concrete which was below ordinary canal level, and the "Universal" brand from the low-water line up. The concrete blocks were reinforced with long wrought-iron bolts placed vertically at intervals and having wide flanges or plates under head and nut. As the concrete work progressed, bolts for snubbing hooks, anchorage to hollow quoins and the gates were built in.

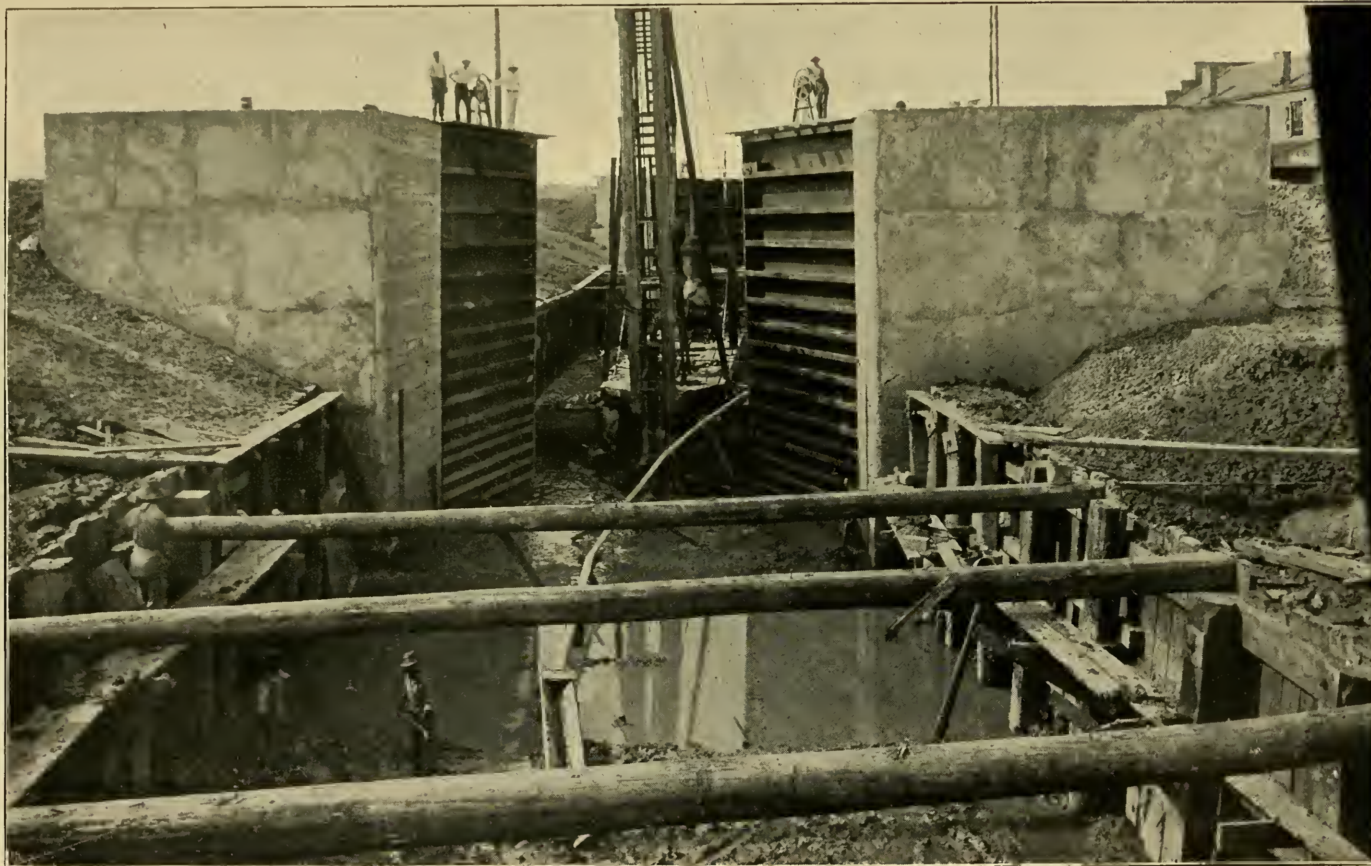
The chamber between the gates is 180 ft. long, and the retaining walls consist of a triple lap pile bulkhead rising about 4 ft. above mean canal level and back filled with earth well sodded with Bermuda grass and sloping to the crest of the levee

with a slope of three horizontal to one vertical. The levee is of the standard type built along the Mississippi River, having a crown 8 ft. wide and slopes of 3 to 1 on each side, and being 3 ft. above the highest water in the river. It is built of clay and sand carefully sorted so as to exclude all wood, brick, trash and foreign material of any character.

The gates are of steel, and as the miter sill is pitched 6 ft. in 16 ft., each gate is 17 ft. 5 in. wide by 29 ft. 3.625 in. in height by 15 in. in thickness. Near the bottom of the gates, where the water pressure will be greatest, the 15-in. I-beams which form the ribs of the gate are spaced only 1 ft. 3 in. apart, and weigh 52 lb. to the running foot; while near the top of the gates they are spaced 3 ft. apart and weigh 42 lb. The irregular spacing near the bottom is due to the location of the wickets of the valves, which are in the gate proper and by means of which the water level is controlled. The skin plates are placed on the river side only and are 0.1875 in. thick. The wickets are comparatively large, having double sluices each 1 ft. by 3 ft. The effect of such large valves, while permitting rapid locking, is to cause considerable swirl and wash behind each gate, which had to be taken care of by a pile bulkhead on each side of the canal for some distance back of each gate, and a wooden flooring extending about 60 ft. back of the gates.

The opening apparatus is of the same type as that used at the Lake Borgne canal lock, namely, a stiffened I-beam made fast several feet below the top of the gate and forced forwards or backwards by means of a worm working into a row of cogs on the I-beam and operated by a hand crank mounted on the concrete blocks.

The quoin posts are hollow, and consist of a vertical I-beam 15 in. @ 50 lb. riveted to each rib of the gate and to the skin plates. Opposite the end of each I-beam are ribs or spreader plates which act as stiffeners to the quoin posts. The skin plates of the quoin posts are polished steel, 0.25 in. in thickness. The quoin posts are eccentric in shape. When seated on the pintles and swung by the opening apparatus, the motion of the post being eccentric to the hollow quoin, friction is rapidly removed, and the post touches nothing but the stirrup at its head and the pintail at its foot after the gate has been opened only a few inches. In order to secure a closer contact between the quoin post and the hollow quoin when the gate was closed, the writer had the pintle reduced in diameter slightly, allowing some play so that the pressure would be sure to jam the gate against the



View Looking Northward.

hollow quoin and prevent leakage. It was feared that too nice a fit would be necessary if no play were allowed, and the fact that the eccentric motion opened a space between the hollow quoin and the quoin post sufficiently wide to accommodate drift and trash, so common in the river and canal water, made some play essential as a safety measure. The wickets are operated by means of a double-geared hand crank, mounted on an "A" frame. The jamb of the gates consists of a beveled cypress stick, nicely fitted and bolted into the channel bar, forming the jamb edge of the gate. The anchorage for the head of the quoin post is quite simple. The pin at the head of the quoin post revolves in a brass bushing seated in an assembly plate which is so arranged as to be easily adjusted. This assembly plate is in turn anchored back with two 0.75 in. upset rods, which are made fast in an iron casting designed for the purpose and securely bolted into the concrete block.

To accommodate the traffic which until now had crossed the canal on the dam near the head of the canal, it became necessary to provide a traffic bridge. The Means & Fulton Iron Works, of Birmingham, Ala., who furnished and assembled the steel gates, also furnished the girder bridge, which was placed 90 ft. in the rear of the rear gate. The foundation of the pier upon which the bridge is turned consists of a cluster of round piles 30 ft. long and spaced 2.5 ft. centers. The piles are cut off to a grade 8 ft. below the lowest water. No caps were used on the heads of these piles, and the concrete was placed directly on them, commencing 1 ft. below the cut-off grade.

The concrete in the pier foundation is reinforced with corrugated steel bars and forms a cylindrical block 14 ft. in diameter and 13 ft. in depth. The bridge is seated upon a truck which rides a circular track and is operated by a ratchet and pinion. The bridge turns on a pivot. The bridge span is 35 ft. in the clear and when closed the ends rest upon substantial concrete shore piers with pile foundations. The roadway is 14 ft. in the clear. The main girders are 70 ft. long, with 0.25 in. web 3 ft. 4 in. high. The joists are 6 in. by 15 in. wooden beams, spaced 4 ft. centers resting directly on the lower flanges of the main girders. This bridge is calculated to stand a dead load of 725 lb. per square foot, a live load of 100 lb. per square foot, a concentrated load equal to a 15-ton road roller with 6 tons in front roller and 9 tons in rear roller, and a wind pressure of 30 lb. to the square foot. The unit stresses required were: Tension girder, 15 000 lb. per square inch; rolled beams, 16 000, and braces

20 000. The web is required to stand a shearing strain of 6 000 lb. per square inch.

The lock was completed in August, 1905, and the official tests prescribed by the Board of Commissioners for the Lafourche basin levee district were started, but the front gate failed, due to the water running under the foundation where the quicksand offered insufficient resistance to water pressure due to a 17.5 ft. head. A 19 ft. head had been prescribed, which had to be maintained for six consecutive hours without showing material leakage. The water in the forebay was still being raised when the failure occurred. As the back gate was ready for test, it was tested by having the water behind the gate pumped down to the floor level, while a head of 19 ft. was placed against the gate. The earthwork adjacent to the concrete blocks was thoroughly wet and allowed to settle for several days, and the water was pumped slowly against the gate, requiring two days to reach the maximum head of 19 ft. The maximum stage was maintained for 6 hr. with no leakage of any consequence developing. The wickets and the opening apparatus were also tested and found to operate satisfactorily. Each gate had to be given two tests, the first with a head of 19 ft. against the front of the gate, and the water behind the gate pumped down to floor level; and the second with water at canal level behind the gate and 19 ft. higher in front. The rear gate was only given the first test, it being decided to make the second test when the front gate was repaired.

The front gate was not wrecked in any way by the failure, except that the earth blew out from under it. The concrete monolith remained intact and no settlement took place, as the concrete rests on the piles which did not move. The failure was, no doubt, due to some defect in the cross rows of sheet piling which were driven into the quicksand with difficulty and must have pulled open sufficiently to let the water pressure through directly against the quicksand under the floor.

The writer recommended replacing the material which was blown out under the flooring with cement grouting, and the cutting off of any leakage under the lock by means of a transverse row of interlocking steel sheet piling, reaching the thin stratum of clay 38 ft. below the flooring and being married into the concrete at its head; the row of piles to be driven immediately along the front or river edge of the concrete work, and to extend clear across the lock and well underneath the levees on each side.

For several months the company debated the question as to whether it would not be safer to abandon the front gate altogether and build a third gate farther back than to attempt the repair of the front gate. It was even suggested that, instead of using the interlocking steel sheet piling recommended by the writer, the quicksand foundation be " set " by driving perforated pipes at stated intervals vertically under the floor of the lock and forcing cement grout into the sand. The writer sought the most authentic information in regard to the use of this method of curing trouble with quicksand foundations, and came to the conclusion that the method would prove more expensive, be more uncertain and require a greater length of time than the remedy already prescribed. Col. F. M. Kerr, chief state engineer of Louisiana, was called into conference and concurred with the engineer in charge.

It was, therefore, decided to follow the recommendation of the engineer in charge in regard to the use of interlocking steel sheet piling. It was then too late to undertake the repair work until after the high-water season of 1905–6, as the pit would have been too close to the river. So work was not started until August, 1906. The work was let by contract and has only recently been completed. The contractor experienced great difficulty in driving the interlocking steel sheet piles, which were of the United States Steel Pile Company type, 38 ft. long, 12 in. wide and weighing 40 lb. to the square foot. The fault was not due to the piles, however, but to the existing conditions, the quicksand and the method of driving the piles. The concrete retaining walls which joined the abutments of the new gate to the old masonry abutments had to be removed by drilling and blasting. That they had been well built was evidenced by the hard work required to cut through them. The trench was then nearly 30 ft. deep in places. The driver had to operate from above the top of the abutments.

The contractor first trenched but a few feet and attempted to use a follower pile through the unexcavated earth. The steel piles, being 38 ft. long, were found to be limber enough to give some trouble in driving them through the unyielding quicksand. A Vulcan No. 1 steam hammer weighing 10 000 lb. was used, and pendulum leads were employed for a part of the time. The engineer in charge refused to allow the contractor the use of a water jet except as a matter of last resort, so the contractor hammered away until the heads of the steel piles were severely battered. The special follower head which had been provided

by the company was discarded by the contractor, as in order to gain stiffness he set up three piles at a time, and these stiffeners were in the way of the follower head. He used a follower head of his own design, namely, a steel plate with angle irons bolted to its under side so as to fit over the web of the sheet pile, while the plate itself rested on the stiffer parts of the pile head. After working for many days, only thirteen piles had been driven to grade, and during the absence of the engineer in charge the contractor abandoned five of the piles which had been only partly driven, and proceeded to interlock and drive more piles further ahead in the hope that they would be found to drive easier and that he could afterwards get permission to drive the five abandoned piles with the aid of a jet. When the engineer in charge returned he found that the contractor had succeeded in driving several piles beyond the five abandoned piles without the use of the jet, and that the wooden half-round calking strips called for in the specifications had been crushed and broomed during the process of driving and allowed to accumulate at the head of the piles, while none of it reached the foot of the piles. The consequence was that the heads of the piles were wedged apart as far as the play of the ball and socket joint allowed, while the feet of the piles were squeezed together. This had given a slight batter to the last few piles driven as compared to the first piles driven, and the space left vacant beneath the five partially driven piles was encroached upon to such an extent that there was not room left for all five piles. In fact, the contractor had gone back to the five piles and hammered them until they were completely locked and jammed, with no hope of either pulling them up or driving them down. He could not even budge the end piles, which were free except for the clinging resistance of the quicksand. A 0.75 in. new wire cable was snapped in an attempt to pull up a 12 in. by 12 in. follower pile which had only been driven 6 ft. into the quicksand. So the attempt to pull the piles up was abandoned and the contractor agreed to blanket the space by driving in front of same Wakefield sheet piles. He failed to drive them even as far as the sheet piles went, even with the use of the jet. As this part of the row of sheet piles was beyond the outer foot of the up-stream abutment it was decided to leave the five partially-driven piles as they were and proceed with the driving of the continuous row of interlocking piles, in the hope that the bulk and weight of the big earth fill constituting the levee over this part of the row would relieve the necessity of driving these five piles all the way down to grade. So great

was the resistance to driving the remaining piles that authority had to be granted the contractor to use a jet. Great caution was exercised not to jet any more than was absolutely necessary. Jetting one pile part of the way down proved sufficient to not only enable the contractor to drive that pile down all the way, but to drive two or three more piles before it again became necessary to use the jet. Five or six piles per day was as much as could be driven under the circumstances.

When the entire row of one hundred sheet piles had been driven to grade, with the exception of the five piles mentioned above, the heads of the piles were married into the concrete floor and abutments so as to cut off seepage or direct flow under the floor. Then several holes were cut through the concrete floor of the lock, on the river side of the miter sill, and a short joint of 8-in. iron pipe was placed in each, with a flange at the top just flush with the surface of the floor. These were set in concrete so as to be left in place after they had been used to fill the voids under the floor caused by the blow-out. To these short joints were bolted in turn a 25-ft. standpipe, 8 in. in diameter. When all was in readiness, a rich, slow-setting, cement grout was poured into the standpipe until it appeared at the top of the pipe. In the first hole none seemed to have found its way under the floor by gravity, so a plunger, made of a length of 4-in. pipe with a piston head fitted on the lower end, was used, and with the aid of the steam hammer some 9 cu. yd. of grout was forced in. When light blows of the hammer refused to force any more grout in, the first hole was sealed, and the same process used on the remaining holes. In this way the void under the floor was thoroughly filled. The trench was refilled and the levees rebuilt and a test of 19-ft. head of water placed against the front of the gate with the water pumped down to floor level behind the gate. The test lasted for 6 hr. under full 19-ft. head, and not a leak appeared anywhere behind the gate.

Now that the repair work to the foundation has proved successful, steps are being taken to comply with the full requirements in regard to the levee surrounding the forebay and chamber, and within a month a further test of the levees will be made, namely, by raising the water 7 ft. higher, both in front of and behind each gate, than was required in the first test, and maintaining it there for six consecutive hours without excessive leakage showing. As the head will be no greater than during the first test, no fear is entertained that the gates will not stand the testing of the levee.

In discussing the method employed, one of the local engineers raised the question as to the necessity of such long sheet piling when the borings showed that the same stratification extended well beyond the upstream and downstream ends of the row of sheet piles, and there seemed to be no reason why the water could not find its way around the extremities of this row of sheet piles before it would come anywhere near diving under the foot of the piling. The writer felt that the failure had taken place immediately under the center of the flooring between the gate abutments, which was the point of least resistance, and that if the original transverse rows of Wakefield wooden sheet piling had failed with 16- and 25-ft. lengths, not to mention the 2-ft. thick solid concrete transverse core 7 ft. below the bottom of the floor, a greater depth should be reached. He felt that it was also desirable that the 18-in. stratum of mixed sand and clay should be reached, but not penetrated entirely. Hence the length of 38 ft. A shorter length of interlocking piling, not extending so far beyond the upper and lower sides of the abutments, might have been sufficient, but as there is no known definite way of determining such a fact, especially when dealing with so precarious and varying a substance as so-called quicksand, the writer allowed what he believed a factor of safety equal to that allowed in designing the strength of the materials used in the gates and the abutments.

[Note. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by September 1, 1907, for publication in a subsequent number of the Journal.]

REINFORCED CONCRETE BUILDING CONSTRUCTION.

An Informal Discussion before the Boston Society of Civil Engineers at its Meetings held September 19 and October 5, 1906.

Mr. Chester J. Hogue. — When the writer was asked to take part in this meeting his first thought was that if he could say something to stir up the concrete experts he might himself take a very brief part and then turn the meeting to his own advantage, getting more information than he would give.

Reinforced concrete of all methods of building construction seems to be attracting the most attention just now, and the design of reinforced concrete at this time certainly furnishes the best field for discussion of any branch of structural engineering.

You are all interested in the developments of engineering knowledge, but you are not all in the fix of some of us who, regardless of what we really know or of what really is known of the design of reinforced concrete, have to assert for the peace of mind of the owners and their confidence in their own buildings that we have completely mastered the science. Among ourselves, however, we may speak a little more freely, and in a short description of a typical concrete factory building the writer will mention briefly the principal points which must be decided to determine the design, and hopes you will see fit to discuss them very freely for the benefit of us all.

Reinforced concrete factory construction, from its ease and economy of execution, rapidity of erection and "everything proofness," seems to be the most distinctive development of this form of construction. On the side of economy the company with which the writer is connected has this year, by careful laying out of the work and study of the wood forms, proven beyond a doubt that a building of this construction can be built at the same cost as one with brick outside walls and wood-framed mill construction interior, and sometimes for even less if the building is high and the loads are great. In general, economy in design lies in using slabs of 8, 10 or 12 ft. span supported by lines of beams in one direction only, these beams resting directly on columns with no girders; but when a wider spacing of columns is required economy is gained by using a slab of minimum thickness, say 3 in. if the finished floor is to

be of wood on top of the concrete, or 4 in. if the finished floor is to be of granolithic laid at the same time as and as a part of the floor, spacing the beams as closely together as this slab will require and framing the beams into the girders at the third or quarter points. In construction the great point in saving of cost is in uniformity of detail and in making the wood forms carefully at first in units and then using the units over and over again as many times as possible. As for speed, we can safely guarantee to complete a building at from eight to ten days a story, and we have this year begun and completed buildings while others of equal size were waiting for their steel frames to be fabricated and erected. Everything proof, it is shown beyond doubt that in recent fires and earthquakes buildings constructed wholly or in part of reinforced concrete gave the best account of themselves; if properly built there is nothing to rot or rust; without hollow spaces there are no retreats for dust, dirt or vermin.

One point, however, shown by a number of recent failures, sounds a note of warning quite independently of the feeling of those who have put years of study into this work, that they alone should be trusted to do it,— that unless engineers and architects are themselves experts in reinforced concrete design and construction and wish to give their work very careful supervision, they should be extremely careful that the men into whose hands they intrust the erection of their buildings should know how to design them, how to build them and should care to do them right; and both they and the owners should realize that first cost does not always mean ultimate economy.

There are two types of reinforced concrete factory construction, the one with concrete outside bearing walls with few openings; the other the skeleton type of construction, the walls being simply filling in panels built afterwards. It is the latter type in which the writer is particularly interested because it is the easier to build and the more economical, and he would call your attention to the following distinctive points. The column and pilaster footings only need go down to a solid bearing unless an excavated basement is required. Where there is a basement, light walls reinforced horizontally from column to column or vertically from the basement floor to the first floor will retain the earth, the reactions being taken by the columns or by the basement and first floor, while the walls may be reinforced to carry themselves from footing to footing, requiring no foundations of their own. Where there is no basement the outside walls

need only go far enough down to prevent frost working in under them with possibly a shallow trench filled with cinders or gravel underneath, and can be reinforced to carry themselves from pier to pier and to support the walls above. By building the footings first and carefully filling, settling and leveling the earth and laying the floor on the ground, the shores to support the false work can be cut of even length and there will be a good level surface to shore from. Columns and floors are built first as in skeleton steel construction and the outside panel walls are self-supporting but not weight-bearing and are built in between the pilasters entirely independently of the floors at a later time, furnishing a convenient method of keeping the concrete gang busy while the concrete floors are setting or the wood forms are being shifted from floor to floor, or when the weather is too wet or too cold to safely permit the laying of the more important work of the floor construction.

Going back now to the question of design, the following list notes a number of important points which must be taken up for decision in designing any reinforced concrete structure:

Footings.

1. Distribution of stresses over tension flange.
2. Proportion of diameter of rod to side of footing.
3. Shear.

Columns.

1. Rich concrete.
2. Longitudinal rods and spacing of ties.
3. Hooped columns.

Beams.

1. Economical proportion of depth to length of span.
2. Spacing of rods in stem.
3. Upper rods bent up where.
4. Length beyond edge of bearing.
5. Allowable width of and distribution of stresses over compression flange.
6. Proportion of thickness of slab to width of stem.
7. Allowable unit shear in concrete when shear is taken by steel in tension.
8. Can diagonally-bent rods, vertical stirrups and plain concrete in shear be utilized together at their working strengths to resist shear, or what combinations can be made?

9. Maximum spacing of shear stirrups.
10. Are round, square or flat stirrups best?
11. Proportion of size of stirrups to depth of beams.
12. Continuous beams.

It is on these points that the writer particularly wishes to start a discussion, and will take them up briefly as follows:

Footings. (1) The footings are reinforced for tension with rods laid in two or more directions as close to the bottom of the footing as protection from rust, etc., will allow. There is no question but that the rods directly under the pier carry their full portion of the load, although the requisite number of rods to properly reinforce the footing may be spread over an area somewhat greater than the width of the pier with a fairly even distribution of stresses over the entire number of rods, but it would seem that as the spread of the rods increases in proportion to the width of the pier above, the stress in the outer rods must decrease, and the distance of the outer rods from the edge of the pier must be limited in some way, possibly by the line of shear of plain concrete, though probably it could be somewhat greater. It seems, though, that this is an important point and that for safe practice some limit should be determined which will avoid over-stressing the rods under the center.

(2) A point of importance in the design of a footing is the proportion of the diameter of the rod used to the length of the rod itself to insure safe anchorage. In a footing rod the maximum tension is at the center, decreasing toward each end, and it may be assumed that the length of rod on one side of the center serves to anchor that part on the other, and it seems to the writer that there should be some definite limit for the proportion of the diameter of the rod to its length, depending on the allowable adhesive stress of steel and concrete. If thirty-six diameters were assumed as giving a safe anchorage to a rod, its diameter should not be greater than one seventy-second of the length of the rod, or practically the length of the side of the footing.

(3) Shear in a cantilever beam differs from that in a beam supported at the ends in that in the cantilever beam, at the point of maximum tension in the rods, there is the maximum increase in stress on the rods and the maximum shear, while in the beam supported at the ends the point of maximum tension in the rods is the point of no increase in stress on the rods and the point of zero shear; that means that in the beam supported

at the ends the maximum increase in the stress on the rods takes place at the end where there is no anchorage beyond, while in the cantilever beam the minimum increase is towards the end and so the adhesive stress on the rod from shear decreases. In a beam supported at the ends it seems to be the adhesive stress on the rods near the end which causes the beam to fail, when there is no steel shear reinforcement, at what seems to be a low-unit shear on the concrete, and it seems for that reason that it is proper to use a higher shearing value on a cantilever beam than in a beam supported at the ends, even though there be no steel shear reinforcement.

Columns. (1) In columns there are three ways of getting the requisite strength. The one which the writer's company most commonly uses — because it has so far seemed to be the handiest and cheapest — is that of a rich mix of concrete, but that is inconvenient for various reasons, as, for instance, if you carry the rich mix up to the under side of the beams and then carry the mixture of the floor and beams over the column, there is a leaner and weaker concrete from the bottom of the beam to the top of the floor slab, and it would be difficult to carry the column mixture to the top of the slab and get the beam and slab concrete laid before the column concrete had begun to set, thus not giving a good bond between the two mixtures, while by building brackets from the column to the beam or by building a capital around the top of the column the increase in the cost of the centering would make it almost as cheap to build a large column all the way down. Then there is the further point that in using two or three mixes of concrete in the same building you can never be sure of getting the right mix in the right place. It is so difficult to get work done as you want it when you are on the ground, even, that it would seem to be useless to expect it to be always done right when you are away; and you cannot be there all the time and ought not, therefore, to take any more chances than you can possibly help, but try to design everything in the simplest possible way. Then again, even if you use a pretty good unit stress on rich concrete, you will find that when you get into a very tall building, or one with very heavy loads on the floors, the size is larger than the owner will ordinarily want to allow.

(2) The next way, perhaps, of getting strength is by using compression rods. Here again are difficulties. The ends of the rods where they bear one on the other at the floor levels should have faced ends and be put into some sort of a socket or tied

together in some way, or else have sufficient lap to distribute the stresses from the upper rod to the lower through adhesion to the concrete. Longitudinal rods, if you wish to have them take the same deformation as the concrete, must be stressed in proportion to the moduli of elasticity of the two materials, and that means that the steel can be used up to hardly half of its ordinary safe working strength, which is far from economical. Then again, if the distribution of stresses at the floor levels is taken care of by faced ends or by lapping enough to transfer the stresses by adhesion, there will still be a good deal higher stresses on the column at the footing than should be allowed unless the rods are to rest on bearing plates. When plain rods are not large enough to give the additional strength required, or rods larger than it would be practical to use are necessary, structural shapes must be resorted to, but structural shapes are expensive and mean delay, they being the slow things to get out of the shops, and they are hard to frame to with concrete, as it is difficult to secure proper bearings for the ends of the beams and girders and to carry the tension rods of the beams through the column in order to get continuous ties through the building and take care of the stresses over the supports.

(3) It seems that the solution of the problem might lie in a hooped column. The writer has eagerly followed developments in that line, although they do not seem to have been carried far enough in the way of tests to know what will be the final results; that is, to know to what extent hooping may be carried and whether as the result of repeated loadings and unloadings the concrete will disintegrate and run out through the spaces between the hoops. In New York, hooped columns have been built where the concrete jackets were cast first and hooped columns built inside of them. It seems to the writer that there is a good point here and that the jackets might be reinforced to a certain extent both horizontally and vertically so that it would not matter whether the concrete inside the hooping disintegrated or not, while the jackets would act as fireproofing for the hooping. In connection with hooped columns there comes up the further questions as to what should be the maximum pitch of the hooping and whether it can be carried to an indefinite extent up to a complete inclosing steel shell or whether there is a limit to its efficiency. In any kind of a concrete column except one in which structural steel shapes carry practically all of the load, longitudinal rods should be put in to take care of flexure from eccentric loads and that sort of thing, and

these longitudinal rods should be bound around horizontally at certain intervals by steel bands of some sort; this is especially important where the rods take part of the compression stresses, in order that they may not buckle and break out of the concrete. There are two limits which the writer does not ordinarily exceed in spacing these hoops, one perhaps a little less than the diameter of the column and the other not more than eighteen to twenty times the diameter of the rods.

Beams. (1) The first point to be determined in designing a beam is the depth, and it would seem to the writer that from one tenth to one fourteenth of the length of the span is a good proportion; that is, a depth in inches equal to the span in feet is usually satisfactory both for stiffness and economy.

(2) The spacing of the rods in the stem is important for the shear on the plane above the rods, for adhesion of the concrete to the rod, for providing sufficient concrete around the rods to thoroughly inclose them, for convenience in placing the concrete between the rods, and for the security of having the rods well protected from fire. If the rods are spaced by proportioning the adhesion of the rods to the shear on the plane above, the other conditions will probably be satisfied. A spacing of two and a half to three diameters is that most commonly used for rods in the same horizontal row, while if there are two rows, one above the other, the vertical spacing is usually about two diameters, although in a number of systems the two or sometimes three rows of rods are placed in direct contact, although this does not seem to the writer to be good or safe practice. If there are two rows of rods and the upper rods are bent up at their third or quarter points, the rods in both rows may probably be spaced as if there were only one row, as the upper rods will act as the tension rods of a belly-rod truss, carrying their stresses directly to the top of the beam; but if there are two rows of straight rods it seems to the writer that the shear must cross the plane just above the rods and be distributed into the rods by adhesion of the concrete and steel and that the spacing should be twice that allowed above unless there are rigidly attached shear members to distribute the increase of stress in the rods into the concrete. For fireproofing, the rods should be spaced not less than two diameters up from the bottom and in from the side of the beam.

(3) When there are two rows of rods in a beam with the load uniformly distributed, the upper ones are usually bent up at their third to quarter point or sometimes even closer to the

bearing. It seems to the writer that there are advantages in favor of the quarter point, as then the rods are not bent up until there begins to be a material reduction in the bending moment, while they will still carry a good deal of the vertical shear. In beams with concentrated loads the upper rods would probably be bent up after passing the last concentration unless this would require them to be bent at an angle greater than 45 degrees. In some systems the rods bend up at different points when they are no longer needed at the bottom for tension, thus taking out shear for practically the full length of the beam, but from the standpoint of comparative economy it would not seem advisable to have to bend rods in so many different shapes, to say nothing of the difficulty of getting the rods properly sorted and placed. The writer is convinced that it is better to keep designs as simple as possible for both economy and convenience, in addition to being surer of having the work done properly in the field.

(4) Rods bent to the top of the beam are supposed to carry their full tension stresses quite to the edge of the bearing, and they must be anchored in some way at or beyond this point. This can be done with plates, nuts and threaded ends when there is no beam beyond, but with an adjacent beam it is advisable to have a continuous tie over the support, so rods may be threaded and connected by means of turn-buckles or by lapping the rods from one beam by those of the other thirty to forty diameters if the rods in both beams are of the same number and size, or by simply carrying the rods over each beam far enough beyond the edge of the bearing to anchor themselves in the concrete if they are not the same in both beams; in this case they should be lapped far enough in addition to their own anchorage to carry the strength of the bent-up rods of the lighter beam continuously over the supports. If the ends of the rods can be turned down this bent end will safely enable the length of the anchorage to be reduced by at least one third. If a beam is not designed for full continuity it is still fixed at the ends to a certain extent by the nature and method of placing the material, and if there is no tensile reinforcement at the top of the beam over the support the deflection due to loading will probably cause a crack at the top near the bearing and this, being at the point of greatest cross shear, should by all means be prevented and sufficient reinforcement placed there to take care at least of the negative moment due to deflection, and it is a question whether a rod bent diagonally from the bottom of

the beam to near the top at the edge of the bearing is sufficient or whether in this case cracks will still take place at some little distance out from the edge of the bearing, requiring tension rods near the top of the beam for some distance out from the edge of the bearing for their prevention.

(5) Leaving the rods now and coming to the compression flange of a T-section, the first point which must be determined is the distribution of the stresses above, vertically and horizontally. Of course we must assume that the maximum compression stress is directly over the center of the stem and it seems to the writer that there is no question but that the stresses diminish on each side of the center to limits fixed by some engineers at three to ten times the width of the stem and by others at from one quarter to one half of the length of the span, but it is a question whether this distribution is rectangular, parabolic or triangular in form. Vertically the stresses will increase from the neutral axis to the top of the slab, the stress diagram being an irregular curve which approaches a straight line at low stresses and a parabola as the stresses approach the ultimate strength of the concrete. It is necessary to assume the distribution in both directions and from this work out the allowable average stress over the compression flange, which will be a variable depending on the proportion of the thickness of the slab to the depth of the beam and the spacing of the beams in proportion to the length of the span.

(6) On the assumption that the compression stresses are distributed over a width of slab somewhat greater than the width of the stem in a T-section, there must be longitudinal shear on the vertical planes where the slab meets the concrete over the stem, and this must equal the shear on the horizontal plane between the slab and the stem except for the amount of compression taken by the portion of the slab directly over the stem. The proportion of the total longitudinal shear which comes on these two vertical planes depends on the proportion of the width of the stem to the width of the slab assumed to be in compression, but as a general rule the stem should not be more than two and one half to three times the depth of the slab; or perhaps it would be more proper to say that the thickness of the slab of a T-section at the planes over each side of the stem should not be less than from one third to two fifths of the width of the stem.

(7) In a concrete beam reinforced with straight rods at the bottom, the limit from shear is the vertical component of the

diagonal tension stresses, and Professor Talbot has shown that in such a beam the vertical shear is equal to the diagonal tension, so that the safe vertical shear should not exceed say 50 lb. per square inch in good concrete. In a T-beam with steel shear reinforcement the conditions are somewhat different, and it seems to the writer that the vertical shearing limit should be the vertical component of the diagonal compression stresses, which would allow the vertical shear to be taken at about three times the value for a beam without shear reinforcement; but it must be remembered that this shearing value must be taken as the unit shear over an area equal to the width of the stem multiplied by the distance from the center of the compression stresses to the center of the tension stresses. It may yet be shown that such distribution of the shear reinforcement; can be made that it will be a question of direct cross shear only, and it is pretty well established that the direct cross-shearing strength of concrete is somewhat more than one half its direct bearing strength.

(8) It is a question in the mind of the writer whether, in a T-beam with both diagonally-bent tension rods and vertical shear rods, the concrete and both sets of rods may be assumed to carry shear at their working strength. It would seem perfectly proper to use the shearing strength of concrete in combination with that of diagonally-bent tension rods, or of diagonally-bent tension rods in combination with vertical or diagonal shear rods, but it seems to the writer that when vertical or diagonal shear rods are used, the shearing strength of a plain concrete beam should not be allowed in addition, because by the time the shear rods are stressed up to their working strength the concrete would be stressed beyond its tensile strength and the rods would be carrying all the stresses whether they were assumed to or not.

Mr. E. P. Goodrich has recently made some tests of beams which he reinforced with vertical shear rods, but not sufficiently to carry all the shear. Tested to destruction, the vertical shear rods were pulled apart, but at a considerably higher load than they could be expected to carry by themselves, showing apparently that the concrete acted in combination with the steel even up to the ultimate strength of the steel, and it may be that by these and further tests the value of concrete and shear rods in combination may be established.

(9) Having established the size of the shear rods to be used, the spacing at the ends of the beam depends on the shear, but

when the shear has so decreased that one shear rod is sufficient, they could theoretically be placed at panel lengths apart. Mr. Goodrich, however, has made tests of beams in which, with the shear rods at panel lengths apart, there were diagonal cracks in the concrete at the failure of the beam, while with sufficient shear reinforcement at half-panel lengths the beams failed by direct cross-shear. This would indicate that with shear rods at panel lengths apart the shearing strength would be the vertical component of the diagonal compression stresses or about one third of the direct compression strength, while with shear rods at half-panel lengths the limit would be direct cross-shear or more than one half the compression strength.

(10 and 11) There are advantages and disadvantages in different kinds of shear rods. Round and square rods will hold better by adhesion in the concrete; but to hold properly, the ratio of diameter to length would have to be sufficient to anchor the rod in the concrete above the neutral axis, while a flat bar could be more depended on for a direct bearing both top and bottom.

(12) The question of continuous beams is very interesting and one which is being given more and more consideration.

Having established the fact that some reinforcement over the supports is desirable to prevent cracking near the bearings, it becomes a question as to whether the negative moment due to deflection should be determined and reinforcement be placed to care for this, or whether you should go further and design the beam for full continuity. This in T-sections requires some provision for taking the negative compression and this may be done by deepening the beam next the column in the shape of a diagonal bracket, or by connecting the tension rods by turn-buckles, or by some contrivance which would give them a direct bearing on each other, while some engineers go as far as to design with simply continuous rectangular beams.

Except in a very simple building beams are not always in a row or of the same length of span; bracketing, turn-buckles and threaded rods are expensive, and the writer hasn't found that a continuous rectangular beam is as cheap as a single T-beam because it does not utilize the compression strength of the slab as a T-beam does. So, assuming that it is safe and proper to design a single T-beam, the writer has yet to be convinced that such a beam properly reinforced for the negative moment due to deflection is not the best and most economical. It is the opinion of the writer that, when concrete buildings are

constructed according to the best method of design and not simply the cheapest, there will be rods placed at the top of beams for their entire length, as well as at the bottom, to prevent cracks from expansion and contraction and unequal settlements of the foundation and to better tie the building together.

MR. LEONARD C. WASON. — The writer has been very much surprised at the great amount of factory work that is being done at the present time in reinforced concrete. A great many inquiries in regard to such construction have been received and more than half of all his work is of this kind. The most encouraging point is that the initiative has in every case been taken by the manufacturers themselves, who have recognized the merits of concrete and desire to use it. The fact that it is being used for all sorts of mill purposes shows very clearly that it is a question of economy rather than of mere adaptability to some particular type of factory work. It is used in textile mills, where there are light loads and rapidly-moving machinery, which is the hardest type of mill construction to meet in price.

In considering the design for reinforced concrete buildings, the design of contraction joints in walls will first be taken up. In early buildings, before there was much experience, very little steel was used in walls or floors to resist contraction, and they used to crack. Therefore the practice of using contraction joints was followed. In early work, fourteen years ago, these were placed at intervals of about 25 ft. As further knowledge was gained, more steel was used and fewer joints, until at the present time there are no limits. The Harvard Stadium, which is 1 430 ft. around, was built with joints that were not expected to open, and only two have opened. A factory now building, 377 ft. long, is tied together from end to end without any joints whatever, the method being to use sufficient steel within its elastic limit to entirely exceed the ultimate tensile strength of the concrete at each section. In this way the steel prevents the concrete from cracking, but the steel has to be placed quite close to the surface to be effective. It is necessary to place it within an inch and a half of the surface to be protected, and the bars must be not more than 10 in. apart, otherwise the concrete is liable to crack.

Walls may be constructed under two general types with subdivisions in the design of each. The most economical is to build piers to support the floor, the floor between piers being sufficiently strong to support a curtain wall. This curtain wall is filled in after the piers and floors are completed, either with thin

monolithic construction or hollow blocks. This curtain wall is bonded into a groove left in the piers to receive it. The other general type which gives the most durable and substantial construction, but is somewhat more expensive, due to the cost of centering, is to build the entire wall monolithic at one operation, the wall being of uniform thickness and solid throughout, or cored to form air spaces between windows and where there are no concentrated loads. These cores can be of such size that the shell outside of core is not less than 3 in. thick. Such walls could be thoroughly tied together horizontally to prevent shrinkage, as above stated.

In the construction of separate footings, the octagonal is preferable to the square. It is very simple to design and build. To center, take four boards, nail together to form a square; nail another of the right length across each corner, and the octagon is obtained. The steel is placed in four directions. Every bar is of the same length and therefore all work with the same stress under the center of the pier. It is possible to use quite shallow piers; that is, the depth can be one third of the projection beyond the edge of the column base, but this is not always wise. A depth equal to one half the spread is a perfectly safe figure to use; that is, the depth from the bearing of the column base to the average depth of the steel is one half of the projection of the concrete beyond the edge of column base. There should be at least 3 in. of concrete below the lower layer of bars to properly embed them and protect them from corrosion. If the size of these bars exceeds 0.75 in., the amount of the concrete below should be equal to at least four diameters. Where footings are placed in wet ground, as an extra precaution it is wise to use a mixture of 1:2:4, which is in itself waterproof, although concrete is such a good protector of steel from corrosion that even in damp places if a rusty bar is thoroughly embedded, in a month it becomes bright. It is economical to use a large bearing-plate under the column, as thereby the stress of the cantilever may be reduced and a saving in cost effected which is greater than that added by the extra size of base. Directly under the column the concrete is subject to cubical pressure and can therefore be loaded to almost any amount with safety. It is necessary to consider only the compressive stress of that portion projecting beyond column base in order to resist the compression from the cantilever action. In a footing of the character here described the shear in concrete can be practically neglected because the shearing stress will always be low.

Columns may be built of concrete or of a combination of steel bars and concrete working together, or as steel column encased in cement. The use of all concrete, using a rich mixture to increase the strength, is the best method, this being the cheapest form of reinforcement possible. One part cement to one part of crushed stone with a working stress of 1 200 lb. per square inch can be used. Tests made at the Watertown Arsenal indicated that at the end of one month the ultimate compressive strength of such a mixture would be at least 5 000 lb. per square inch, and therefore 1 200 lb. would be perfectly safe. Of course using this method implies that considerable care must be exercised in mixing and placing. On large work which is being executed rapidly, without this care it might happen that the wrong mixture would be used in a column. This, of course, would be dangerous, but no practical difficulty has been experienced in changing mixtures and seeing that special batches were placed where wanted. Of course it is necessary to carry a mixture right through the thickness of a floor as well as through the column. This can be easily done by placing vertical boards in the girders and beams meeting at the column, filling the rich mixture inside and the floor mixture outside, afterward drawing out the boards while both mixtures are still wet and are filled to the same level. In columns designed for concrete to sustain the entire load, use vertical steel in the piers only as a safeguard against possible eccentric loading or flexure and to obtain a rigid joint with the floor. If rich mixtures are carried to an extreme, columns might be too small in cross section. It is unwise to make any column nine or more feet long less than 10 in. square.

When the load is divided between steel of any section and concrete, the stresses are distributed in the proportion of the moduli of elasticity of the two materials. Taking the ratio of the modulus of elasticity of steel to concrete as 10 and the working stress of concrete as 500 lb. per square inch, which corresponds to a mixture of 1 : 2 : 4, gives only 5 000 lb. per square inch as the compressive stress in the steel. With richer mixtures the ratio is less while the stress is higher, and the result is but very little different.

After concrete has set for a month it begins to shrink and continues to for about six months, when it reaches its limit. During the first month the adhesion between the concrete and the steel becomes considerable, although it does not reach its maximum strength. The above-mentioned shrinkage when the

concrete is exposed to the air on all sides amounts to 0.015625 in. to 0.03125 in. in length of 12 ft. Taking 0.024 in. as an average shrinkage, this shortening is equivalent to that produced by a stress of 500 lb. per square inch. As this exceeds the tensile stress of concrete, this latter stress, being about 300 lb. per square inch, may be taken as a force producing compression in the steel and by the reaction of the steel producing tension or reducing compression, as the case may be, in the concrete. It is on account of this reaction of the steel producing tension in the concrete that the tensile stress is used rather than the larger force which would produce a shortening equivalent to 500 lb. per square inch. This tensile stress multiplied by the ratio of the moduli of elasticity would permit an additional stress in the steel of 3 000 lb. per square inch, and when combined with the load a total stress of 8 000 lb. per square inch, and in the concrete an apparent stress of 800 lb. may be used, which in reality, however, is only the 500 first mentioned.

In the actual construction of a building the concrete has about a month to set before any considerable portion of its ultimate load is brought upon it, no matter how rapidly the structure may be erected, and as a well-designed structure should carry its maximum load when a month old, the above allowance of stresses is legitimate and safe.

The adhesive bond between steel and concrete is at least equal to the tensile stress. In some experiments it has been found to be very much greater. This is sufficient to transmit from the concrete to the steel, in the thickness of a floor, the increment of stress the steel must take through the story below. Thus the concrete is not overloaded in transmitting the stress from a floor to the steel in the column below. The bars should be faced and set on top of each other, being held in position by a sleeve. When bars are lapped, as is sometimes done, at the top of the splice, the concrete must take more than its proportion of the load coming upon the column in order to transmit to the lower bars in the length of the splice that portion which they are expected to sustain. Through the length of the splice the concrete is receiving more than its allowable working stress. This method of design is in somewhat common use, but it is not a safe method unless the concrete can carry a large part of the total load, and when it can the steel is of little value.

By increasing the size of the footing so that its cross-sectional area is more than equivalent to the area that would be required if plain concrete were used to carry the entire load of column,

and by making it deep enough to absorb by adhesion the load carried by the steel, a bearing-plate may be omitted at the bottom, but this style of footing is expensive. It is always better to use a base plate of sufficient size to distribute the load from the steel bars over the footing. It can then be made shallow, as is usual, and economy results. In the Ingals Building in Cincinnati the columns in basement were about 34 in. by 45 in. in section. Near the center were two bars 4 in. in diameter and four bars 3.3125 in. in diameter to assist in carrying the compressive load. Near each of the outer and inner faces were five 1-in. square twisted steel bars to resist possible flexure and to make a rigid bond between column and floors in order to resist flexure due to wind pressure. The load to be sustained was 1 550 000 lb. A cast-iron base-plate was used having a planed seat for each of the six large bars and enlarged to a bearing area on the footing of 4 ft. 10 in. by 4 ft. 7 in. This base-plate weighed over a ton. It is better to have a few big bars near the center than many small ones near the surface when they are designed solely to carry a compressive load.

By actual tests conducted with care at various testing laboratories it has been demonstrated that the steel does not sustain as large a load as might be expected from the above discussion. In a large enough number of cases to form an average, the columns carried but slightly more load than plain columns of the same dimensions and identical mixture. These tests indicated that the reinforced columns were not enough stronger to justify their use from an economical standpoint.

The combination of structural steel and concrete can be illustrated by describing one actual design. In a seven-story warehouse the roof and upper three stories were carried by concrete alone. In order to avoid too large a size, a structural steel column was used from this point to the ground. Two stories were carried by the steel work entirely. The two lower stories were carried entirely by the fireproofing of the steel, which in this case was made a little heavier than would be necessary for mere fireproofing purposes. Let it be emphasized that the two lower stories were entirely independent of the steel column within. This result was obtained by using countersunk head rivets to produce as smooth a surface as possible and by covering the steel with a jacket which was sufficient to prevent any bond between it and the surrounding concrete and to permit either to compress independently of the other. In construction the steel columns were first erected, the casing concrete of basement

was put on, first floor cast, the jacket continued and the second floor cast. In the third and fourth stories the covering was for fire protection exclusively and so far as the design was concerned could have been omitted until the building was nearing completion. This method reduced the amount of steel required because the two lower stories were supported independently while the concrete jacket was but little larger than would have been used any way for fire protection. A net saving thus resulted without an unreasonable size of column in the lower stories.

Hooped concrete columns are of little value and should never be relied upon in ordinary designs. In order to get the value of the hoops, the concrete must be compressed a considerable amount in order to cause a measurable lateral expansion, and when it has been thus compressed the safe working stress has been greatly exceeded, which is not a wise thing to do. Hooping should only be used as an added factor of safety to provide against occasional unusual heavy loads which last for a short time only in places where a large column cannot be used.

In regard to beams, so much has been written in the technical press that it is very little use to say more. There are, however, a few points worth considering, more particularly on the practical than on the theoretical side, because the theoretical side has been pretty well covered. From a practical point of view stirrups are quite useful. In ordinary construction work workmen sometimes fill in all the beams first and then fill in the panel cross-wise later, starting at one side and working to the other, so that by the time they have reached the end the concrete in the beam has begun to set. As the work is figured so that the panel acts in compression with the beam, there are liable to be serious results. Therefore the stirrups are very useful to bind beam and panel together. The stirrups used in American practice to a large extent are useless, because they do not extend out into the panel. They should have a projection into the panel of at least a foot. Then the beam and panel are well bonded together. Experienced designers use them partly for that purpose, especially near the center of the span. If the whole floor is cast as a unit, of course stirrups are not necessary as a tie between beam and panel, but this is not always a convenient thing to do.

Once, years ago, the writer made a very careful study of long span floor design to get the relation of spacing of beams to panels for the maximum economy, taking into consideration the

cost of materials and the cost of labor as it then existed. That study led to the selection of 3-ft. centers for the maximum economy. If the spacing is increased, weight is added to the beam and to the panel; and if it is reduced, the cost of centers is increased without a compensating saving on concrete and steel. This was the spacing which gave under those conditions the maximum of economy. This study has not been revised, but it is the writer's opinion that under present conditions, with the high price of lumber, which makes the beam floor much more expensive to center than the slab, and the higher price of carpenter labor, the spacing would be increased from 3 to about 4 ft. for maximum economy. The practical considerations of mill design often require a different spacing. For instance, concrete floors are frequently held to the old form of mill frame construction; that is, beams 8 or 10 ft. on centers and a flat slab between. This is less economical, but it is often necessary, and the difference in economy from the cheapest design is not very great.

A method of beam reinforcement which is coming into quite general use and ought to become more general, is that of knowing exactly where and how the steel is set. If it is put in loose, it is likely to be misplaced while filling in the concrete; but if rigidly made up into units and anchored at their ends to other units or the wooden form, they are held exactly where they belong until the concrete is filled in; therefore the construction really agrees with the design. The recent type of construction of bent-up bars crossing one another or fastened together over the columns has forced into use one variation in design, namely, the joints between various days' work. Years ago they used to be made directly over columns. The beams and girders which met on the column were made double and one half was cast on different days. But now there is such a network of steel there that it is almost impossible to put up wooden forms to stop off the concrete, and therefore the custom has come into use of making joints in the middle of spans. This is much easier to do from a practical standpoint, and from the theoretical standpoint does not weaken the construction in the least because the tension of the concrete is neglected in the design. Better work is obtained from ordinary laborers with joints in the center of the spans than with split beams. After the concrete is thoroughly set there will be a shrinkage which pulls it away from these joints, and if they are over a column this shrinkage has sometimes split the column. To avoid this the plan was adopted

years ago of using a steel plate, also hoops, to allow the beams to slip without splitting the column. This is now avoided by making the joints in the center of the span. However, this change requires considerable reinforcement of the top surface of panel over beams and girders at right angles to them in order to avoid tension cracks along their top surfaces. There is one point in designing that ought to be emphasized until its use is universal, namely, that all work ought to be designed on the basis of the working stress instead of the ultimate stress with a factor of safety.

Some of the types of construction discussed are claimed to be covered by patents. Some are valid, while others, doubtless, are not. The so-called continuous girder where bars bend up and run across support to unite with others from adjoining span is probably a valid patent. Many have been using it without consideration of patentees and if it is done wilfully those doing so are likely to come to grief sooner or later. Also, there are some patents on the so-called girder frame which have to be considered. But as a general thing all patents recently issued are so narrow in their claims and are so easy to avoid that the desired result can be obtained without infringing on anybody else's rights.

Concrete placed around steel reinforcement of necessity has to be mixed considerably wetter than is necessary when placed in large masses. The right amount of water for reinforced concrete is that at which the concrete just quakes when tamped or spaded. At this consistency it will flow properly around the bars. If more water is used the stone can settle through the mortar somewhat as through water; thus the concrete would become of uneven density. By laboratory tests it has been found that the concrete which just quakes differs but little from the maximum strength obtained with the best consistency in plain concrete, which is a plastic concrete that does not quake. Extremely wet concrete which flows nearly as freely as water never develops as great strength as plastic concrete.

Mr. Joseph R. Worcester. — I should like to say one or two words on the general subject of the use of reinforced concrete for mill construction. There are some difficulties about it that must necessarily be met face to face. The principal one, I think, is in the size of the columns. I think there is a general feeling among architects and owners that reinforced concrete columns ought to be built as small as steel columns, and the owners and architects have been forcing contractors to use

every possible device for reducing the size of columns, and the contractors have allowed the reduction to go further than is really safe in many instances. I think we must recognize the fact that we cannot build a reinforced concrete column as small as a steel column and that if we are going to use such a column we have got to give it more space. This does not amount to much in a low building, of course, but in a high building the loss in space amounts to a great deal.

Personally, I do not approve of either of the methods of reducing the size of columns advocated by the two previous speakers. I think the objections each has raised against the system of the other are very well taken, and I should say you cannot properly reduce the size either by enriching the mixture to the extent that Mr. Wason advocates or by using the hooping which Mr. Hogue is in favor of. I think Mr. Wason's point against hooping is exactly right. If you put your coil of wire into the form and then put in your concrete, the tendency of the concrete if anything is to shrink away from the wire. It certainly is not going to enlarge and bring the wire into tension, and in order to get the wire into effctive action some motion has to take place in the concrete within the wire. The Watertown Arsenal tests have shown that this motion is accompanied by deformation of the column, and I have understood from Mr. Howard that in his opinion the concrete is considerably disintegrated inside the hooping before the hooping has come into play. On the other hand, Mr. Hogue has said that with a rich mixture it is pretty hard to take care of the joints at the floor levels, and I believe he is right. Mr. Wason says it can be done, but I don't believe it can be done very safely. If you stop off your column under the floor girder, then the floor mixture bears directly on the rich mixture. That will overload the floor mixture, which is not so rich. If you carry the column mixture up through the floor there is danger of a crack, pretty nearly vertical, between the mixture in the beam and that in the column. There is, therefore, a point of weakness either way. So that it seems to me that we must start with the idea that we are going to have a pretty good-sized column, and unless we are going to have plenty of room for this, we must regard it as an objection to the construction.

Another point of difficulty in using concrete is the exterior of the building if it is made of this material. So far as I am aware, the last word has not been said as to the best method of finishing an outside wall of concrete. Nothing has been said

about it by the previous speakers, and I don't propose to advocate any method of treatment, because I don't know which is the best. There is a great liability to cracks in any concrete finish, and it is doubtful whether the durability of the outside finishes used thus far has been fully demonstrated. I don't say this too positively, but I think we must learn a great deal more with regard to exterior finishes.

One other objection to concrete construction is that the loads upon footings in a reinforced concrete building are heavier than in the case of wooden framing, and where the foundations are soft a good deal more expense is involved than in the case of wooden framing. This, perhaps, is not a serious point, but it has to be considered.

Now, a word as to the mill building Mr. Hogue has illustrated. It is apparently his intention to start the wall at the ground level. This does not seem safe on account of the fact that frost is liable to work in under and disturb the floor. This danger may be obviated by carrying the wall down below frost level, but it is not good practice to lay the first floor right on the fill unless it is remarkably good material, because it will settle and then you will have cracks. It is better to have some cellar with posts and to have the lowest floor self-supporting.

With regard to details, I wish Mr. Hogue had given us more information as to what he uses in his own practice. He has raised a lot of questions for others to answer, but it would have been of great advantage to us if he had given us the benefit of his own answers to these questions. Possibly we should not agree with him, but we would certainly like to know what his opinions are in regard to these matters.

His method of figuring footings may be scientifically correct, but I must plead guilty to a much simpler way of figuring these parts myself, a way which may not be correct, but if it is not I should like to be made aware of it. Where I have a square footing I take half the resistance of the earth on each set of rods. I assume that the rods in one direction take half the upward pressure and that the rods in the other direction take the other half. I assume that we have two central cross-sections at right angles to each other, each of which is virtually an inverted T. That is, in figuring this cross-section, I assume that the only value of compression we have in the concrete is the width of the top of the trapezoidal cross-section. I think that if you figure your two sets of rods in that way and take half the pressure on each, you get safe results, so far as I am aware. I think we

must always take into account the shearing force which Mr. Hogue referred to. My practice is to allow 100 lb. to the square inch on the area obtained by multiplying height by perimeter, and not to consider the diagonal tension as we would in a beam.

With regard to the spacing of rods in the stem of beams, Mr. Hogue said that horizontally he spaced them from 2.5 to 3 diameters from center to center. There is quite a difference between 2.5 and 3. I am rather in favor of 3 myself, for the reason that the shearing area above the rods in that case is about equal to the circumference of the rod, and you have about the same unit in shear which you have in adhesion, which I think is about right. There is quite a pressure brought upon engineers sometimes to allow a closer spacing, even down to 2 diameters from center to center. That seems to me a dangerous practice. As far as the spacing vertically, which Mr. Hogue referred to, goes, I can't see any great objection to the practice of the Hennebique Company of putting two rods one over the other in contact. I would like to know if this is really unsound from theoretical reasons. I haven't been able to see them myself.

So far as lapping the rods at the end is concerned, I cannot see why it is not all right to lap far enough so that the strain in one rod may be transferred to the rod in the opposite direction by adhesion, and if you consider 40 diameters of the rod sufficient to develop its strength, it seems to me that a lap of 40 diameters is sufficient to transfer the strength from one rod to another close by.

I will say one more word in answer to Mr. Hogue's questions in regard to continuous beams. There are several objections to considering beams as continuous and to methods in use for making them continuous. In the first place, if you have real continuous construction, you want to have more tensional strength at the top of the beam over the support than at the bottom of the beam at the center. That, of course, means that you have more compression at the bottom over the support than at the top at the center of the span, and where you use T-construction, as we do almost altogether, this means that you cannot use as much steel by a good deal as we like without overstraining your beam in compression. Mr. Hogue suggests that that can be relieved by the use of bracketing, but on the top of your bracket, between the bracket and the beam, you are almost sure to have a joint, because you fill up to the bottom of the beam and lay the beam afterwards, and you have a weak spot there for transference of shear into the bracket. Then, again, it seems to me that it is

not good engineering practice to assume that your beam is fixed over a support when it is only so fixed either by stiffness in the column or by the live load in the adjoining span. You have very little stiffness in the column and you can't count on the live load in the adjoining span. It seems to me that it is better practice to figure your beams as if they were supported at the ends. While I do not believe in figuring on the continuity, it is, nevertheless, necessary to reinforce to some extent at the top over the supports, and that is a thing that cannot be emphasized too much. If you allow any sort of concrete construction to go over an approximately fixed support without being reinforced at the top over the supports, you will have cracks in the surface where they will be very conspicuous. This reinforcing at the top may be thrown in as added security.

Mr. Wason referred to joints which he makes in the centers of his beams as " contraction joints." I don't see how they can be " contraction " joints where your reinforcement runs through, as they must at the bottom of the beam. They are really set joints, but I do not see how they can be contraction joints.

PROF. LEWIS J. JOHNSON. — I am not often inclined to disagree with Mr. Worcester, but I think there is something to be said on the other side of this question of continuity of reinforced concrete beams.

The question seems to be, Shall we or shall we not count on continuity in the design of slabs, beams and girders? This question proceeds upon the assumption that it is beam action and not arch action which is to exist. This assumption is almost universally adopted and is doubtless correct unless in cases where the ratio of depth to span is exceptionally great. More attention is likely to be given to this question of arch action than has been given to it in the past. But, granting beam action to be the proper basis of design, I cannot see how any one can doubt that it is continuous beam action that should be provided for. Slabs, beams and girders are continuous beams as built, and for better or for worse are going to act as continuous beams if they act as beams at all.

Objection to recognizing this fact in design seems to be based upon the supposition that designing beams as continuous would lead to mid-span sections good only for positive bending moments of about 1-40 wl^2, a figure which would be nearly correct for a load distributed uniformly over all spans at once, but would be fatally in error in the case of the far more probable instances of unequally distributed load.

Objection of a similar sort is applicable to design upon the basis of discontinuity, where ultra-cautious design for a mid-span bending moment of $\frac{wl^2}{8}$ is accompanied by a more or less complete ignoring of the negative bending moment of the supports. The assumption of simple beam action may thus prompt serious error on the side of danger quite as certainly as similarly improper application of the assumption of continuous action. That trouble from this source has not been more abundant I believe to be due partly at least to the undoubtedly considerable tensile strength of the concrete in the wings of T-section beams and girders. But if it is not safe to count on tensile strength of concrete elsewhere, it is not safe to count on it here.

The logical course to pursue is to recognize that, if the action present is beam action at all, it is continuous beam action, and to design accordingly. This means careful attention to the extreme values of the flexures at supports as well as at mid-spans due to all possible distributions of the live load. The end sections are then designed to meet these extreme conditions, and so are the mid-span sections. This is standard practice among the Germans and Swiss, and it ought to be in this country, and I believe is going to be. Of course in applying this method, as in any careful design, attention will be given to all important facts, such as stair or elevator wells interrupting the continuity in places; and in cases of doubt, assumptions unmistakably on the side of safety will, of course, be made.

The labor involved in these computations is not so great as it would seem. As a matter of fact, the extreme conditions under uniformly distributed live load will almost always be covered in case of a series of beams and slabs of equal spans by designing for a live load flexure of 1-10 wl^2 (l being measured from center to center of supports) at the faces of columns and girders, and the same amount at mid-spans; and this, too, regardless of the number of spans in the line. At the column faces flexure would be negative and at mid-spans positive, and in both cases would, of course, be combined with the dead load flexures. If the spans are short and the live loads large in comparison to the dead, top reinforcement may be required at mid-span to provide for resultant negative flexures there existent.

The similar extreme values for girders subject to concentrated loads have not been so well established, but the need of them is recognized and it is hoped that they may be forthcoming soon.

If a designer prefer, let him use 1-8 wl^2 at the mid-span section, but let him not fail to provide fully for the bending at the faces of the supports.

He must not overlook the fact that top reinforcement over supports is as logical a requirement as bottom reinforcement at mid-span.

Moreover, there is additional justification for top reinforcement in that it is of the greatest possible value in case of weakening of bottom rods by fire. The top rods through cantilever action may carry the load after the lower rods, in the far more exposed position of the two, have failed. In fact, top reinforcement does not seem to have had the attention which its merits from the fireproofing standpoint would seem to entitle it.

It may be objected that continuous beam coefficients based upon the assumption of unvarying moment of inertia may be inapplicable to reinforced concrete beams. This is certainly a fair field for research, but the practitioner may well proceed for the present with his 1-10 wl^2, taking comfort from realizing that the negative bending moment over supports would not rise above $\frac{wl^2}{8}$ even in the extreme case in which the moment of inertia becomes zero at mid-span, — the case of two abutting disconnected cantilevers, — a case most unlikely to occur. The error in the 1-10 wl^2, if any exist, must be extremely small and unimportant.

For beams under a uniformly distributed load, the top steel at the column faces and through the column may or may not be the same in amount as at mid-span, depending upon the relative depth of the beam at the two points, but I see no escape from the belief that the negative moment of resistance at the column face should be as large as the positive moment of resistance at mid-span. If, as is usual, floors are figured with T-sections, this may call for the German practice of materially deepening the stems at and for considerable distances each way from the supports, to make up for the absence of flanges on what is here the compression side of the beam.

This leads to brackets at connections of girders to columns and of beams to girders. These brackets complicate the forms and are usually unsightly. They can be obviated by making depth of stem at mid-span as great as required at the column faces, proportioning bottom steel at mid-span accordingly. This interferes with head room and adds to the quantity of concrete required. It may in some cases be practicable to diminish this depth by use of steel reinforcement in the compres-

sion lower side of the beam at the support. Though this latter reinforcement would also be effective and necessary reinforcement from the arch point of view, the brackets will in many cases be preferred to either of these alternatives.

But continuous beam action, I believe, is with us, and with us to stay; is, in fact, unavoidable. It must be reckoned with and patiently and properly provided for in all reputable reinforced concrete practice. Above all things, let us here as elsewhere adhere to the policy of preparing at all points of a structure for the most unfavorable conditions reasonably to be expected. And, finally, let us not go on imagining that we err on the side of safety when we ignore continuous beam action.

Turning now to what I came here to say, I wish to place on record some very high and perhaps unprecedented values for unit shears and unit adhesion stresses. These results were obtained in the beam tests of which I had the honor to give you some preliminary account last May. They are results obtained in the actual working conditions of a beam, and computed, as seems clearly proper, by the same methods which one should use in designing a projected beam or girder.*

* The particular methods which I have in mind have been in use in Europe and, to some extent, in this country for several years past, but as I believe they are still somewhat unfamiliar, and as they are as simple as they are logical, I will venture here to state their deduction.

Let Fig. 1, AB and CD, be two right sections of a rectangular beam with single reinforcement, the distance between them, Δx, being so short that the vertical shear, V, at one section differs only immaterially from that at the other. Call the bending moment at the two sections M_1 and M_2, respectively. Then, as is well known, $M_2 - M_1 = V \Delta x$. If b be the breadth of the beam, the maximum unit shear may be written,

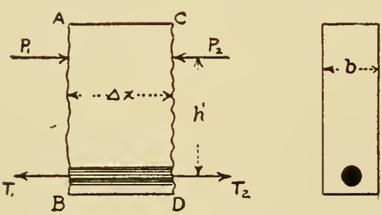


FIG. 1.

$$f_s = \frac{P_2 - P_1}{b \Delta x} = \frac{T_2 - T_1}{b \Delta x}$$

as will be realized upon observing that the total horizontal shearing tendency is the amount by which P_2 differs from P_1, which is the same as the difference between T_2 and T_1, and that the unit shear is the total horizontal shear divided by the area, $b \Delta x$, on which it is resisted.

But if h' be the distance between the centroids of tension and compression, that is, the arm common to the resisting couples composed of P_2 and T_2, and P_1 and T_1, respectively, then

These results were gained from beams 3 in. wide, 9 in. deep over all, and 8 ft. long. The steel reinforcement was 8 in. from the top of the beam, and the amount in all cases was 1 per cent. of section above the steel. The rods included smooth round, cold-twisted square and Johnson corrugated. The Johnson rods were in all cases perfectly straight, but the others were some straight and some hooked up about 3 in. at ends, and some of the smooth round rods had each end bent around a short piece of 1.125 in. rod, which thus formed a somewhat loose anchor. In no case was there an anchorage plate or washer.

$$P_1 = T_1 = \frac{M_1}{h'} \text{ and } P_2 = T_2 = \frac{M_2}{h'}, \text{ and}$$

$$P_2 - P_1 = T_2 - T_1 = \frac{M_2 - M_1}{h'} = \frac{V \triangle x}{h'}$$

Substituting this value in the expression for f_s, there follows

$$f_s = \frac{V}{bh'}$$

an expression valid, by the way, for the maximum unit horizontal shear (or vertical, of course) in any rectangular beam, whether of concrete or other material and for rectilinear or curvilinear stress distribution. The only difficulty in the application of this expression is in getting the value of h'. This value depends on the percentage of reinforcement, but for ordinary percentages and ordinary assumptions as to stress distribution in the section, h' will differ but little from 0.875 h, where h is the depth of the beam to the center of gravity of the steel. In a homogeneous beam of depth d, h' is, of course, $\frac{2}{3}d$.

Similarly, for the unit adhesion, f_a, to the steel,

$$f_a = \frac{T_2 - T_1}{U \triangle x}$$

where U is the sum of the perimeters of all the rods resisting T. $T_2 - T_1$ is the force which must be resisted by adhesion in the section and $U \triangle x$ is the surface of steel available for the purpose. Putting in the value $\frac{V \triangle x}{h'}$ for $T_2 - T_1$, as before, there follows

$$f_a = \frac{V}{Uh'}.$$

For example, if, at a section of a beam where there are three 0.5 in. round rods 8 in. below the surface, the shear is 7 000 lb., the adhesive unit stress on those rods will be, taking the closely approximate value of h' given above,

$$f_a = \frac{7\,000}{\frac{3\pi}{2} \times 0.875 \times 8} = \frac{1\,000}{4.71} = 212.3 \text{ lb. per sq. in.}$$

This deduction for f_a, it will be observed, is based upon the customary assumption of absence of tensile stresses in the concrete.

The loads were applied as shown in Fig. 2.

A slip sufficient to break an electric contact rang an alarm bell and the behavior of the rods as to slip was thus carefully watched.

Two grades of concrete were used; one was of proportions 1: 2: $2\frac{2}{3}$, the stone being scaly trap; the other, 1: $2\frac{1}{2}$: 5, the stone and sand being in this case of a character to permit a leaner

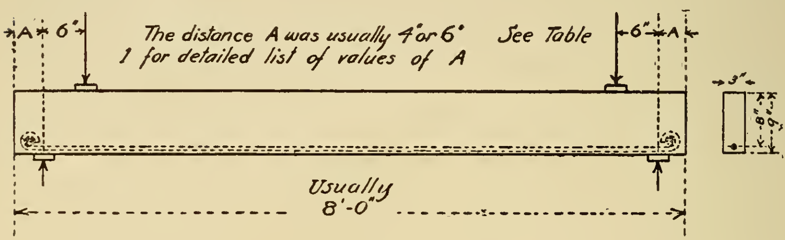


Fig. 2.

mixture. The two grades will be referred to as rich and lean respectively.

In all, twenty-five tests of this kind were made, nineteen of them on rich beams and six on lean, and as might, perhaps, be expected, failure was due *in every case* to slip of the reinforcement, regardless of the kind of rod and the conditions of the end. Consequently the actual shearing strength of the concrete was never realized, and the values given are merely the values of the shearing stress in existence at the time when the adhesion gave out. In none of these twenty-five tests were there stirrups or diagonals or other web reinforcement.

The shear thus developed averaged, in the six tests of lean beams, 470 lb. per square inch, with extremes of 573 and 233; average age, 143 days; age of extreme values, 138 days for smaller, 137 days for larger.

The shear similarly developed in the nineteen tests of rich beams averaged 628 lb. per square inch, with extremes of 750 and 488; average age, 50 days; age of 53 days for the higher value and 50 days for lower.

All of these values may, of course, be taken as horizontal or vertical shears indiscriminately. Considering that these values were in no case ultimate values, and considering that bending stresses were by no means excluded, these results add to the evidence now steadily and convincingly accumulating that the actual shearing strength of concrete has been greatly underestimated. They confirm the growing belief that failures have

been attributed to shear that were due to slip of rods or diagonal tension, phenomena closely connected with shear, but still should not be called shear.

The adhesion stresses developed in the six tests of lean beams averaged 774 lb. per square inch, with extremes of 970 and 427 lb. per square inch. The 970 figure was for a perfectly straight unmodified cold-twisted rod in a beam 137 days old. The 427 for a similarly unmodified smooth round mild steel rod, this last a figure about twice what is usually expected of such rods.

In the rich beams the average of adhesion stresses in the 19 tests was 1 094 lb. per square inch, ranging from 913 for a smooth round mild steel rod with ends hooked up, through 960 for a similar rod without the hook, to 1 367 for a similar rod bent around an 1.125-in. anchor rod as shown in Fig. 2.

The results in detail for lean and rich beams, together with the values of "A" (see Fig. 2) in each case, are as follows:

TABLE I.

Kind of Rod and Condition of End.	Lean Beams.		Rich Beams.	
	f_a lb. per sq. in.	"A" in.	f_a lb. per sq. in.	"A" in.
Rods straight and unmodified:				
Smooth round mild steel............	427	4		
Smooth round mild steel............			960	7
Smooth round mild steel............			1 194	17
Johnson corrugated................			1 182	7
Johnson corrugated................			1 232	9
Cold-twisted square................	853	4		
Cold-twisted square................	970	4		
Cold-twisted square................			1 073	7
Cold-twisted square................			1 155	9
Cold-twisted square................			1 161	15¾
Cold-twisted square................			940	12
Rods turned up at the ends:				
Smooth round mild steel............	790	4		
Smooth round mild steel............			1 266	7½
Smooth round mild steel............			893	6
Smooth round mild steel............			913	6
Cold-twisted square................	854	4		
Cold-twisted square................	753	4		
Cold-twisted square................			1 178	6
Cold-twisted square................			1 185	6
Cold twisted square................			936	4
Cold-twisted square................			1 102	6
Rods turned around a 1.125 in. anchor rod (Fig. 2):				
Smooth round mild steel............			918	6
Smooth round mild steel............			988	6
Smooth round mild steel............			1 135	5½
Smooth round mild steel............			1 367	6

Hardly less striking than the high adhesion values in all these tests are their comparative uniformity regardless of differences in types of rods and end conditions, and the unimportant difference between the results for smooth and deformed rods. In fact the last beam of the series would suggest that by a very simple and natural modification smooth round rods may surpass their more pretentious and energetically advertised rivals.

But it must not be forgotten that the conditions in these tests were of an extreme nature, and the inference must by no means yet be drawn that such high results are to be expected under other conditions of loading. These peculiar conditions may include something which would render the method of computing f_a inapplicable, but it is hard to suggest just what it could be. It would seem that such abnormally favorable action as might have been present in these tests would be equally likely to be present in an actual building under similar loading conditions. Possibly a vise action as result of compression of the concrete on the under side of the beam at the support due to the very high end reactions and consequent gripping of the rods may have been in operation, but if this had been the case one would hardly suppose there would have been so great a disparity between the results for the lean and the rich mixtures. The lean would be likely to deform more and lead to a tighter grip, but yet the results do not substantiate this view at all.

More plausible is the suggestion that even with this load, unfavorable as it was for producing deflection, the beams were sufficiently bent to interfere materially with slip. This, however, is a condition of practice, and nothing to invalidate the results from a practical point of view.

It should also be stated that with other and more usual conditions of loading, slip occurred with considerably lower values of f_a than the ones above given.

Whatever the value of adhesive stress actually developed in these 19 rich beams, the fact remains that the *ultimate* strength of the 9 of them which were reinforced with smooth round rods ranged from 4.5 to 6.5 times what our customary methods of figuring and ultimate stresses would have led us to expect.

And whether the adhesion stresses as given are correct or not, the 25 beams do afford a fair basis of comparison between the two mixtures of concrete as well as of the rods and their end conditions. What I have called the lean mixture is not believed to be an uncommonly lean one from the point of view of ordinary

American practice, and that I have called rich is probably not so rich as the common European mixture as used by the best practitioners. Yet the difference between these two mixtures is striking. The rich concrete showed 42 per cent. higher average results for f_a than the lean, showed very much less variation from the mean, and furthermore were obtained at scarcely more than one third the age. It is noticeable that the disparity between the smooth round rod and its rivals is vastly greater in the case of the lean concrete than in case of the rich, as was to be expected.

If arch action was the prevailing condition, the advantage in favor of the rich mixture is not so clear as otherwise because, with the rich mixture the " A " was almost always greater than with the lean.

The nearest recorded approach to these results for f_a, so far as I am informed, are those of Kleinlogel described in *Beton u. Eisen*, 1904, page 227. His beams were of 1: 1: 2 mixture, reinforced with smooth round rods absolutely unmodified or bent, without stirrups or mechanical anchorage. The span was 6 ft. 7 in. and the beams were loaded at the quarter points. Size of beams was 6 by 12 in. Age not clearly stated, but was not less than five (5) months. His maximum f_a was 550 lb. per square inch (an average of a set of four beams just alike), and *was not an ultimate* value, but like the shear values above recorded merely values realized when failure occurred some other way. The percentage of steel was 0.094. In Kleinlogel's case the failure was due to stretch of the steel between the supports and subsequent crushing of the concrete. The portion of the beams outside of the loads showed no sign of failure whatever and the adhesive strength had clearly not been reached. It is easy to believe if his beams had been loaded as were the ones in Cambridge, failure by bending would have been deferred until f_a reached as large values as those I have given. His maximum value of shear, f_s, was 470 lb. per square inch, and failure in this case was attributed to diagonal tension.

Kleinlogel attributes considerable importance to the deflected condition of the beam (carrying with it, of course, a slight bend in the rods) as increasing the f_a and, very properly I think, deprecates the customary attempt to reason from results from straight pulls of imbedded rods out of blocks to the resisting power of a rod in actual service in a beam.

Professor Talbot's maximum value for unit adhesive stress upon smooth round mild steel rods in his series of 1905 was only

193 lb. per square inch, but this was not an ultimate value, for failure was to be attributed to causes other than slip. His loads were applied in a way not intended to develop extremely high values of V, while in the Cambridge beams just described of course high values of V were deliberately sought.

These very high values of adhesive stress and shear are presented for record and discussion and I cannot make it too clear that I believe the high adhesive results, at least, may be due, perhaps must be inseparably connected with, the very exceptional method of loading and should by no means be taken as a basis for design until further investigations are made. Either the results are valid as they appear, however, or there are circumstances in which the customary methods of figuring do not apply; if the latter, the reason is yet to be sought. The promising direction for the search, in my opinion, is arch action.

However all this may be, the tests certainly do encourage the hope that richer mixtures will remove much of our reasons for fear of adhesion or shear failure.

So far as verticals or other web reinforcement are concerned, there are results from other beams of that series of tests which have come to light since last spring which are worth reporting briefly at this meeting, pending more detailed publication later. They are as follows:

Some 60 to 70 of the beams of the lean mixture were loaded at the quarter points in a span of 88 in., making the space between loads 44 in. The size and amount of reinforcement the same in general as in the 25 beams loaded as in Fig. 2, except that about half of them had web reinforcement either vertical or diagonal. The vertical consisted of so-called U-bars or stirrups, and pairs of disconnected straight rods thrust into the concrete after filling the molds, the U-bars and the pairs spaced 6 in. apart measured along the beam. The diagonal consisted of Kahn bars with their wings as well as the bent-up (Hennebique fashion) portions of the main reinforcing rods, in that case smooth round rods.

The rods included round and square smooth rods of low as well as high elastic limits, Johnson corrugated, cold-twisted square, and a variety of end conditions, turned-up ends, nuts and loose washers and ends turned around anchor rods as in Fig. 2.

In the beams with vertical reinforcement the main reinforcement included all those enumerated in the preceding paragraph, but in those beams the main rods had ends with no

modification. The special anchorage of the main reinforcement was in no case combined with vertical reinforcement.

From these 60 or 70 lean beams it appeared that on the whole the best showing, so far as postponing the " first crack " (I mean visible crack) is concerned, came from beams with no web reinforcement whatever, either vertical or diagonal. The rods in some of the best of these cases had nuts and washers at the ends, and the very best had the rod ends turned around another rod as in Fig. 2. But it is not clear that end conditions were the determining influence, for smooth round rods with nuts and washers were surpassed in cases by similar rods perfectly straight and unmodified. There seemed to be no advantage in high elastic limit over low.

For ultimate strength in the same set of lean beams, the best results come with the web reinforcement, with smooth round rods with nuts and loose washers without web reinforcement a good second.

Unfortunately the rich beams loaded at the quarter points were only five in number, reinforced respectively with smooth round mild steel, smooth square mild steel, smooth square high carbon steel, Johnson corrugated and cold-twisted square, *all* (deformed rods and all) with a nut and loose washer at each end.

The twisted rod led to the highest first crack result of all, higher than the very best of the lean beam results, and all four others closely bunched alongside the best of the lean beams with the smooth round rod a little ahead of the remaining three.

The highest ultimate results from this lot of five rich beams came from the high-carbon (elastic limit, 71 200), closely followed by Johnson corrugated, next the smooth round, and the twisted square, and worst of all the square untwisted mild steel rod; all rods, be it remembered, had nuts and washers at the ends.

The two best showed much higher ultimate results than the best of the lean mixture, though the latter had web reinforcement and the former did not. The next two were about even with the very best of the lean mixture, and the worst of the five was surpassed by only few of the lean beams. The rich beams were about 103 days old and the lean 150 to 175 days old.

All this would tend to show that a rich concrete, or straight rods with nuts and washers, or both, is the most hopeful means of getting the best results both from point of view of the first crack and of the ultimate strength, and that web reinforcement, whether vertical or diagonal, is comparatively of doubtful utility from these points of view. In lean concrete the verticals at

least seem to tend to uniformity of strength, and to slower, more gradual failure.

And it should be carefully borne in mind that the washers used in those tests were the small, thin, standard washers and not secured against the nut except by the concrete as it was packed. Useful as such washers proved, they did not altogether prevent slip except with the round smooth bar, and I believe they would have shown better results still if they had been larger, thicker and secured against the outer nuts.

Richer mixtures than customary, and more carefully designed plate end-anchors and common round rods will accordingly be my next line of study.

I heartily agree with Mr. Wason's plea for uniform figuring of working loads, and I also want to urge the propriety of the general adoption in this country of the practice of the Germans in using what I haven't used until within six months myself, but I am now convinced it is best, — and that is a straight line distribution of stress with a ratio of 15. This is a practice thoroughly established in Germany and it gives, as a matter of fact, results almost absolutely identical with the parabolic distribution with a ratio of 10 such as I used to use.

Another point I have had forced on my attention lately is what we want for a factor of safety. That is a question that has not been asked to-night, but I think the factor of safety a good many times is lower than stated. It seems to me that we ought to insist on a factor of safety of 2.5 against the first crack. I think that is a good place to stop — 2.5 for the first crack and 4 or 5 for ultimate. The first crack seems to be a pretty serious matter.

Mr. Sanford E. Thompson. — One of the leading questions scheduled for discussion deals with the design of columns, and at the risk of presenting matter which is familiar to those who are constantly engaged in design, the importance of the subject leads me to include in the course of my remarks a somewhat elementary discussion for the benefit of many who have not the time to study the subject in detail.

Column Design.

It is generally accepted that some steel reinforcement shall be placed in concrete columns, but the best method is by no means settled. Many designers use very light reinforcement, such as four 0.5 in. to 0.75 in. vertical rods, with horizontal hoops spaced no greater distance apart than the width of the column, or,

on the other hand, no greater distance apart than 30 times the diameter of the hoops, the reinforcement being simply to assist in taking bending stresses and to guard against cracking. Others adopt larger vertical rods up to 4 per cent. or 5 per cent. of the area of the column, this steel being calculated to take a portion of the direct loading. Some designers employ hooping either in spiral or circular form, which is figured to take a circumferential tension produced by horizontal expansion of the concrete due to the vertical load.

A direct means of increasing the strength of the column is by using a concrete or mortar very rich in cement. Still another plan which has not been mentioned in the discussion is the selection and grading of the aggregates to produce a dense and strong concrete. Altogether too little advantage is taken in practice of this means of increasing the strength. While in many cases it is not permissible from an economical standpoint to grade the aggregate, in the construction of columns every increment which may be added to the allowable load is advantageous because allowing a proportionate reduction in the size of the column.

The use of longitudinal rods to increase the strength of the column per unit of area, and therefore to reduce its size, is not economical unless the space occupied by the columns is of considerable value, for the reason that it is usually impossible to load the steel to its full working strength. If steel imbedded in concrete could be given a working load of 16 000 lb. per square inch the cost of increasing the strength by vertical rods might not be more than the cost of increasing the area of concrete to obtain an equivalent increase in strength. For example, if a working load of 400 lb. is assumed for the concrete, the unit strength of the steel would be 40 times the unit strength of the concrete. A linear foot of steel 1 in. square at 4 cents per pound would cost 13.6 cents, while a linear foot of concrete 1 in. square, if the concrete is figured at 50 cents per cubic foot, would cost 0.35 cents, a ratio of cost of 39, or substantially the same as the ratio of strength assumed. On the other hand, as is apt to be the case in practice, if the steel, because acting with the concrete, cannot be loaded beyond 8 000 lb. per square inch, its cost for equal strength will be double that of concrete in the assumed case.

The fact should not be overlooked in discussing column loading that the preponderance of tests indicate very conclusively that longitudinal steel, if properly imbedded, does actually take a portion of the load and that it ought to be considered in

figuring the strength of the column. The reason for the low efficiency which is normally attained by the steel is not simply the difference in moduli of the two substances, but also the difference in their strength. As the column takes the load it is shortened in height, and the concrete, while more compressible than the steel, has so much lower strength that it receives its allowable load before the steel can reach its working strength. We frequently hear the assertion that the steel does not receive its full load because of its higher modulus of elasticity. This is not true. If the concrete were capable of taking as high a unit load as the steel, the steel because of its higher modulus would reach its working load first and the concrete, instead of the steel, would be insufficiently stressed. As a matter of fact, then, the reason for the low stressing of the steel is because the ratio of the strength of the steel to the strength of the concrete is greater than the ratio of their moduli. The relative loading upon the steel and the concrete at any period is theoretically in direct proportion to the ratio of their moduli of elasticity.

Since the mathematical derivation of the formulas relating to the combined action of steel and concrete in compression is seldom presented it may not be out of place to give it at this point.

Let C_1 = unit pressure upon reinforced column.

C = unit pressure upon the concrete of the column.

S' = unit pressure upon the vertical steel in the column.

$r = \frac{E_s}{E_c}$ = ratio of modulus of elasticity of steel to modulus of elasticity of concrete.

A = area of total cross-section of column.

A_c = area of concrete in the cross-section.

A_s = area of steel in the cross-section.

$p = \frac{A_s}{A}$ = ratio of cross-section of steel to total cross-section of column.

The values of C_1, C and S' may be taken either as working stresses or as ultimate stresses, although the former is preferable.

From a fundamental law in mechanics,

$$\frac{\text{stress per square inch}}{\text{modulus of elasticity}} = \text{deformation.}$$

Thus,

$$\frac{S'}{E_s} = \text{deformation in steel} \tag{1}$$

and

$$\frac{C}{E_c} = \text{deformation in concrete.} \tag{2}$$

Since with perfect adhesion between concrete and steel all parts of the column must undergo the same deformation,

$$\frac{S'}{E_s} = \frac{C}{E_c} \qquad (3)$$

or,

$$S' = Cr \qquad (4)$$

Formula (4) gives the relation of the unit pressure in the concrete to the unit pressure in the steel, but for practical use the total unit pressure or load in the column must be introduced.

The entire pressure in the column must be the sum of the pressure in the concrete plus the pressure in the steel; hence,

$$C_1A = CA_c + S'A_s$$

or from formula (4)

$$C_1A = CA_c + CrA_s$$

And since

$$A_c = A - A_s$$

we have

$$C_1 = C\left[\left(\frac{A - A_s}{A}\right) + r\frac{A_s}{A}\right]$$

or, since

$$p = \frac{A_s}{A}$$

we reach the result,

$$C_1 = C\,[\,(1 - p) + rp].$$

The following table is calculated from the formula with different variables:

WORKING LOADS IN CONCRETE COLUMNS REINFORCED WITH LONGITUDINAL RODS.

Ratio of Steel.	Allowable Unit Load on Columns, C, Pounds per Square Inch.					
p.	Ratio of Moduli, $r=10$.		Ratio of Moduli, $r=15$.		Ratio of Moduli, $r=20$.	
	C=400	C=600	C=400*	C=600	C=400	C=600
.01	436	654	456	684	476	714
.02	472	708	512	768	552	828
.03	508	762	568	852	628	942
.04	544	816	624	936	704	1 056

NOTE: C represents the allowable loading on a plain concrete column in lb. per square inch.

In selecting the modulus of elasticity for concrete to use in column design it seems to me fair (and this opinion is borne out by various tests at the Watertown Arsenal) to employ not the elastic modulus but the modulus based on the deformation before deducting the set. Strictly, the set should not be deducted from the steel either, but since the set in steel during

* This column may be used for ordinary 1:2:4 concrete.

early loading is extremely small, it may be neglected and the modulus of the steel figured in the usual way.

Tests made by Mr. Howard at the Watertown Arsenal, which are recorded in the "Tests of Materials," 1905, indicate that the formulas given above are conservative; in fact, that the actual strength of the column longitudinally reinforced is usually in excess of the theoretical strength. I have selected several of the mortar columns which give the comparative strength of plain columns and those reinforced with about 3 per cent. steel.

Actual Strength of Plain vs. Reinforced Columns from Tests at Watertown Arsenal.

Proportions.	Plain Column. Lb. per Square Inch.	Reinforced Column. Lb. per Square Inch.
1 : 2	3 700	4 200
1 : 3	2 700	3 800
1 : 4	1 600	3 400
1 : 5	1 100	2 800

For hooped reinforcement, formulas have been evolved in Europe from tests of Considère and others, and many designers in this country have adopted this method of reinforcement for the purpose of satisfying the demand for concrete columns of size approaching that of steel columns. In many cases this has resulted in the use of 1 000 lb. per square inch for unit working pressure, while in several cases which have come to my knowledge pressures in columns built of concrete in ordinary proportions with spiral hooping have run as high as 1 500 lb. per square inch. I am not ready to adopt these high unit pressures, and I believe they are unwarranted by tests thus far published either in this country or abroad.

The theory of the hooped columns assumes that the hoops or spirals confine the concrete and by preventing lateral expansion increase the load which it will bear to a degree dependent upon the area of steel in the reinforcement. Unquestionably, if concrete be confined as in a tube so as to produce what is sometimes termed "cubical compression," the load may be increased without actual failure to any limit which the tube or other surrounding medium will withstand. However, tests indicate that in practical construction, as pointed out by previous speakers, the concrete is probably overstrained before the hoops can take an appreciable load. Mr. Howard, at the Watertown Arsenal, measured the lateral expansion of a number of plain columns (that is, with no reinforcement), which are reported in "Tests of Materials," U. S. A., 1905. With concrete such as 1 : 2 : 4, the

lateral expansion under a load of 1 000 lb. per square inch was about 0.001 in. If such a column had been encased in a spiral, computations based on the deformation of the steel and of the concrete show that the maximum pull which could be attained by the steel in the spiral is about 2 500 lb. per square inch. In other words, even with an infinitesimal area of steel in the spiral, the horizontal expansion or deformation of the column due to the vertical loading of 1 000 lb. per square inch would have been only sufficient to produce a stress or pull in the hooping of about 2 500 lb. per square inch. As the area of the steel in the spiral becomes a practical quantity the stress in it becomes even less than 2 500 lb. per square inch.

The Arsenal tests further illustrate the action of the concrete by lateral measurements upon the column after excessive loading. In an experiment where the concrete column was loaded nearly to its breaking point and the load removed and then gradually replaced, the lateral expansion of the column under the same loads as before was very largely increased, the expansion under a load of 1 000 lb. per square inch being now 0.004 to 0.006 in. The elastic limit had evidently been passed in the first loading. The column which I have indicated had no hooping, but if it had been hooped it is evident that in the latter part of the test, after the concrete had been overloaded, the steel spirals would have taken a fair amount of pull. Is it conservative design, however, to permit so high pressures in the concrete itself at any period, and is it not possible, nay probable, that the concrete may be so structurally damaged that repeated loading or vibration may produce not merely cracks, but entire disintegration of the concrete within the hoops?

Undoubtedly hooping does increase the strength of the column, but unless the hoops form a continuous tube or else are near enough together to prevent the concrete from crushing out between them, it is questionable whether the use of steel in this form is really economical if the working stresses in the concrete are held within safe limits.

I had the pleasure of witnessing one or two of the tests at the Arsenal upon full-sized hooped columns. In a general way it appeared to me that the hooping increased the strength of the column so that the strength at the time of the first crack was approximately the same as the strength of a cube of similar concrete. In other words, the hooping counterbalanced the effect of the length and increased the unit strength of the column to the unit strength of a similar cube.

Pressure in Beams due to a Negative Bending Moment.

Referring for a moment to the compression in the bottom of T-beams at their supports, due to negative bending moment, it seems fair when figuring the strength of the lower portion of the beam in compression that we should take into account the compressive strength of the steel reinforcement which extends across over the column. Thus, suppose there is 2 per cent. of steel in a T-beam, — this 2 per cent. being figured upon the beam exclusive of the flange, — and suppose that half of this, or 1 per cent., is carried over the support in the lower portion of the beam, then this steel will be found by computation, using the ordinary formula for steel in compression, to be equivalent to a considerable area of concrete, and will assist in providing for the compression due to the negative bending moment.

Bending of Steel in Slabs.

The report upon a series of tests upon slabs which has recently come to my attention illustrates the advisability when shaping the steel for bent-up rods in a beam or slab to make the bends at an obtuse angle instead of at nearly a right angle, as is sometimes done. In the experiments referred to, a portion of the tests were made upon continuous slabs of three spans, fairly uniform loading being attained by four independent heaps of pig iron on each of the spans. A part of the rods in the slab were bent up about at the one-quarter or the one-third points (I am not sure which), and in nearly every case the first crack occurred at a point which approximately coincided with the point at which the bends — which were nearly right angle bends — occurred. The cracks usually started at about one half of the ultimate strength of the slab. A similar set. of simple slabs reinforced with horizontal rods and supported simply at the two ends showed scarcely any crack until very near the ultimate strength of the slab, this ultimate strength being nearly the same as the ultimate strength of the continuous slab.

The cracking in the continuous slabs was probably due to the fact that as the steel in tension approached its elastic limit its area was slightly reduced by the pull, and the length of the horizontal portion of the bent-up rods was insufficient to give sufficient adhesion to the concrete, hence there was a tendency to slip, which caused the rod to partly straighten out at the bend and crack the concrete there.

Another line of discussion which it would be profitable to take up is the matter of safe working loads which it is proper to use in design.

MR. F. H. FAY. — One thing I should like to ask Mr. Thompson and that is, in the matter of columns, whether any special provision is made to take the stress from the steel at the ends of the column? In other words, if it is not taken out, what becomes of it? Is it taken by direct bearing on metal supports at the base of the column, or what other way is it taken care of?

MR. THOMPSON. — Provision should be made for transferring the stresses at the lower ends of the rods into the footing by plates or washers or some other means. This is an important point and is always considered in good design.

MR. FAY. — That is what I was getting at. It seems to me highly important to provide some means of getting your stress properly out of the steel reinforcement into the column foundation.

MR. WILLIAM PARKER.— In one case the stress referred to is taken from the column into the footing by running the bars down through the footing so that there is length of bar imbedded in the footing sufficient to transmit the stress, which the bar received from the column, into the footing concrete. From the top of column base, about at the basement floor, the vertical column bars, which in this case are corrugated, extend about 4 ft. into the mass of concrete of the column base and footing slab.

PROFESSOR JOHNSON. — I think that point is very important, and it is interesting, I think, to note that — certainly in some of the best-known cases of tests on longitudinal rods — no provision is made for taking care of the concentrated stress at the ends of the steel rods. I think tests under such conditions should be scrutinized very carefully before being taken seriously.

MR. HOGUE. — May I ask, in regard to carrying the rod down into the footings, were they reinforced footings?

MR. PARKER. — They were reinforced at the bottom.

MR. HOGUE. — Well, should not there be length enough between the top of the footing and the neutral axis to anchor the rod?

MR. PARKER. — There is a reinforced footing in the form of a slab and then there is a mass of concrete above the footing which is smaller than the footing but much larger than the column; that is, there is an intermediate cube and the column rests on this intermediate cube, the bars extending down through this cube, which is about 3 ft. thick, and also extending into the reinforced slab nearly to the bottom.

Mr. Hogue. — That is, a bearing larger than the column and smaller than the footing between the bottom of the column and the footing. If that column rested directly on the footing, it probably should be distributed within the compression area, should it not?

Mr. Parker. — Yes.

Mr. L. S. Cowles. — It is probably a fact that the outer columns of a building will receive their figured loads more quickly than the inner columns, owing to the fact that the inner columns have a greater amount of live load. Now, in case the outer columns have settled more than the inner columns, is the reinforced concrete structure capable of withstanding the strain resulting from this unequal settlement? I was wondering whether such unequal settlement would be a detriment to the reinforced beams and the columns on the inside; that is, if there is sufficient elasticity to prevent injury to the beams in that case.

The Chairman (Mr. Worcester.) — That is a very interesting question, and some of the engineers here who are interested in the subject ought to answer it.

Mr. Hogue. — There is one thing which I should like to say in this connection, and that is, that I think sooner or later it is going to be much more the practice for an owner to go to an engineer and have his building designed before it is figured on. And when that is done we shall be in a position to do some things that we cannot do now. As it is now, when we contractors have to make our own designs and estimate on them in competition, we can't afford to put in any more steel than enough to keep the building up. I am looking forward to the time when owners will have buildings designed first, so that we can all estimate on the same reinforcement and have plenty of it. I think if there were rods at the tops of the beams they would take care of the strains arising from unequal settlement. Perhaps some of you noticed recently a picture of a building in Tunis, I think, — a reinforced concrete factory building, six stories high and about 50 by 100 ft., the foundation of which was entirely gone under one corner and the building was toppled over to an angle of 10 degrees, and yet the structure was standing there uninjured except in the foundations, and they were going to jack it up and put a new foundation under it. It is a good example of what reinforced concrete will stand.

Mr. Parker. — I'd like to ask Mr. Hogue to tell us, in answer to the gentleman who spoke a minute ago, if his experi-

ence does not go to show that most of the buildings are designed now-a-days in the very way that he speaks of; that is, having plenty of steel in the top and bottom of the beams, and having them so that they are practically continuous beams?

Mr. Hogue. — There is almost always steel at the top of the beam over the support, and possibly for a little way out, but usually the middle half of the beam is without reinforcement at the top.

Mr. E. R. Olin. — At the last meeting, as I remember it, Mr. Hogue favored reinforcing columns by using hoops, while Mr. Wason did not believe in the use of hoops, but in the use of a richer mixture, and I think Mr. Worcester said that each had condemned the other's method in suitable terms. I wish each of those gentlemen would reply to the objections of the other to his particular style of construction of columns.

Mr. Hogue. — I am afraid the gentleman misunderstood me a little bit. What I said was that I hoped I might be able to favor a hooped column, because it seemed to give a smaller column to carry the same load than any other kind of design. I think, myself, the rich concrete column which we use in our practice has so far been the best, because we feel safest and surest of it and know the most about it. I think that when a rich concrete column gives too large an area, or on account of the difficulty of using two different mixtures in a building, the best way to increase the strength is by using compression rods, taking the bearing at the bottom with some sort of plate. But the objection I advanced to that was that there must be some way of distributing stresses from one tier of rods to the other, either by faced ends, in which case they should be put into a socket, or by a long lap to distribute the stress from one to the other, but both those methods are expensive, as is also a bearing plate at the bottom, and it seems to me that if it could be shown that the hooping of the column could be used, it would do away with a good many of those difficulties. But the question in hooped columns is whether the concrete will flow sideways without being injured or whether it will disintegrate. If we could safely design it I think there are great possibilities for the hooped column. The difficulty there, which Mr. Howard has brought out plainly, is that the richer the concrete the slower it is in stretching the steel hoop into tension, and for that reason you reach almost the ultimate strength of the concrete before that takes place. You can make concrete so rich that you can reach the ultimate strength before the hooping is much if any good.

Then there is another difficulty, whether if you use a mixture, which will expand sufficiently to stress the hooping, it will not disintegrate. For that reason I do not think that hooped columns have been carried sufficiently far in tests to justify us in using them to any extent. But I hope something may be developed in that line.

Professor Johnson. — I do not want to be understood to be expressing an unqualified approval of hooped concrete, but it might encourage those who, like myself, are hopeful on the subject, to hear that Monsieur Considère, in the last number of *Beton u. Eisen*, seems to be more enthusiastic now than ever before, and says he has a great quantity of additional data ready to publish which is much more important than anything he has done yet, and speaks of obtaining a stress of 22 400 lb. per square inch in compression on concrete. So it seems that there is something more of importance to be expected from him. So far as column reinforcement is concerned, there is a kind of column reinforcement being used now in New York which consists of structural steel-latticed angles filled entirely with concrete. There is structural steel present in sufficient quantity to support the dead load of the building, and concrete in addition to take care of what live load may come. The steel columns in the bottom story of that building consist of four 8 by 8 angles, latticed in the ordinary way, with rivet heads sticking out to insure coöperation between steel and concrete. It certainly is effective in keeping the size of the columns down.

Mr. Edward S. Larned. — I do not wish to add anything to the theoretical discussion of this subject at this time. Some important features connected with this work, however, have not been touched upon by any of the speakers, although I think you are probably all alive to them. In the course of ordinary work some of our pet ideas are very much upset.

At the September meeting of the New England Water Works Association the concrete steel standpipe of Attleboro came up for discussion. In this work a high carbon steel was used, and the standpipe was of circular construction, with diameter of 50 ft. It appears that they had much difficulty in bending the steel to the radius, and found it expedient to hold the rods together at the splice with guy clips. There was a great deal of spring in the steel, however, and it was found difficult to keep the bars in position while the concrete was being placed, and Mr. F. A. Barbour, consulting engineer, expressed the idea that in case the steel became displaced during the earlier hardening of

the concrete, it might, in reaching its final position, pull away from the concrete, leaving a void. This I have often heard suggested in connection with concrete beam and floor construction. A practice which is coming into much use to overcome the difficulty is to jar the forms with mallets while the concrete is in a semi-fluid condition. This seems to settle the steel into position quickly and at the same time secure a very good bond between the rods and the concrete. I regard it as a most excellent practice.

I am very glad to know that the importance of the question of the consistency of concrete is coming to be more generally recognized. It was only a short while ago that engineers using concrete assumed that they could not get it too wet. In some cases they made no distinction between Portland cements and natural cements, using both of the same consistency, this, in the past few years, meaning very wet.

In speaking of the consistency of concrete, engineers express their views in such indefinite terms that it is difficult to determine when a man describes a condition just what he means.

It seems to me that in making concrete for reinforced structures it should be as nearly as possible scientifically, uniformly and thoroughly prepared. We take great pains in fixing the dimensions of the gage box for sand and stone, and it seems to me that proportions of water should be as definitely fixed and kept within reasonable limits, depending on the size and character of the sand and stone aggregates.

The influence of mechanical mixing contrasted with hand mixing has a very important bearing on the consistency of the concrete and its appearance; for example, take hand-mixed concrete, where engineers require dry mixing before the introduction of water, then two, three or four turns; these turns with one gang of men mean one thing and with another gang mean something entirely different. Some men are trained to turn it vigorously, others simply roll it over, and at best the mixing is very imperfect. In mechanical mixing this variation is avoided and a more intimate and better mixture is bound to result.

In proportioning water for mechanical mixing, it is possible to use a less amount of water and yet produce a concrete of a consistency that would compare with hand-mixed concrete using a much greater amount of water. You will observe this fact if, after determining the amount of water to be used, you hold it in the mixer for a few extra turns and it appears much wetter than if you used more water and turned it out in a shorter in-

terval of time. In other words, I advocate that the mortar in concrete should be of such consistency as to readily support the aggregate and cause it to cling together, and by proper mixing with a moderate amount of water this will result in a concrete very plastic, easily flushed, productive of smooth exterior surfaces against the forms when properly handled and resulting in the densest and consequently the strongest and most water-tight concrete.

When the question of introducing concrete through intricate reinforcement becomes serious, this must be met by reducing the size of your aggregate and perhaps making it slightly wetter, but carefully avoiding the sloppy condition which one commonly notes these days.

Because of the difficulties of handling and placing stone concrete about the reinforcement of the Attleboro standpipe, Mr. Barbour has expressed the idea that had he this work to do again he might consider the use of a clear mortar without coarse aggregates, feeling that by so doing there would be less chance of voids, and it would be easier to secure water-tight work.

Professor Johnson. — I should like to call attention again to the subject of unit stresses. I wish there could be some discussion of what are fair working stresses in spread concrete footings. I should like to offer the suggestion that 100 lb. per square inch be looked upon as admissible there in what may be called punching shear, and also that 100 lb. per square inch be looked upon as satisfactory adhesion in the case of smooth, round rods in a footing. I don't know whether those figures are such as will excite comment or not, but I wish they could be discussed.

The Chairman. — Has anybody any comment to offer upon Professor Johnson's challenge?

Mr. Thompson. — The value for shear suggested by Professor Johnson, 100 lb. per square inch, is the same as mentioned by Mr. Worcester in previous discussion. I believe that this is conservative and that we may eventually reach even a higher figure for our safe unit stress for punching shear in concrete of fairly rich proportions. The experiments upon shear have given extremely varied results. In some of the tests made in Europe * very low strength has been found at first crack, even as low as 80 lb. per square inch, with an ultimate strength of, say, 360 lb. The experimenter acknowledged, however, that the strength at first crack was lowered because there was more or less transverse

* See S. Zipkes in *Cement*, March and May, 1906.

stress. This also probably affected the ultimate strength. By using reinforcement to provide for transverse stress he obtained an average of 300 lb. per square inch at first crack and 700 lb. ultimate strength. In all of these tests the proportions were 1 : 3, but the age was only 50 days. Tests at the Institute of Technology, on the other hand, where bending was eliminated, gave something like one half of the compressive strength. Tests by Feret with mortar also have shown very high shearing stresses, these being one half to two thirds the strength of similar mortar in compression.

Professor Johnson. — I don't think there is any trouble in getting compressive strength enough in the footings under any circumstances. But this question of adhesion and shear, it seems to me, is where the difficulty lies. And therefore I feel a little hesitation in following those tests reported by Professor McKibben, because the case there was so extraordinarily favorable to the development of a high shear. In actual footing we don't get conditions quite so favorable as that, even granting that the case is unusually favorable. In the case of shear, I have seen 500 to 750 lb. per square inch developed in a beam without failure due to that cause. So personally I feel safe about the 100 lb. per square inch for shear, though I hesitate to go further. As to adhesion, apparently the Germans have taken a backward step. They used to consider 100 lb. per square inch satisfactory for adhesion, but the building regulations of 1904 put it back to 63. I think the Germans went the wrong way.

If I thought 200 lb. per square inch were a proper measure of ultimate adhesion of concrete on smooth rods, I should not feel safe with 100. I should not think it anywhere near safe. I do not think the proper way to measure adhesive resistance as it occurs in beams is to take a rod and pull it out of a block by a direct pull from the testing machine. In a beam the rods are under circumstances which are totally different from those in the cases mentioned. It may not be out of place to call attention to figures I have obtained myself in beams and which I mentioned at the last meeting. I have cases here of 25 different beams in which the adhesion did not go below 500 and in one case reached 1 367 lb. per square inch, figured in the same way as one would figure adhesion in designing footings. I have 960 lb. per square inch as a result obtained with perfectly smooth, straight round rods in a very rich mixture, somewhat richer than we use in practice, but no richer than we ought to use. I have a figure of 850 and one of 970 on cold-twisted

rods. That is with a lean concrete, 1 : 2 ½ : 5. Those figures, running from 500 to 1 300 lb. per square inch, cannot be set aside. European results are in a similar direction, and Europeans criticise, as I think they should do, the study of adhesion by pulling rods directly out of blocks. They think the results developed in actual tests and in the testing machine should be figured by the same method. So far as the shear is concerned, in 19 cases of beams tested under my own observation there was developed in a rod from 500 to 750 — something like that — in tests involving very marked bending. It was not a case where bending had been excluded, but where distance between support and load was from 3 in. up to 6 in.

Mr. Hogue. — It seems to me that in designing a footing, which is in effect a cantilever beam, the question of direct punching shear is not as important as the average shear over the depth from the center of compression to the center of tension or the panel shear. While in a plain concrete beam — a beam supported at the ends and without vertical shear reinforcement — it has been established that we don't want to use more than 50 to 60 lb. per square inch in shear, I think that it can be greater in a cantilever beam, because there is a different relation of the increase of stress and shear in a cantilever beam from that in a beam supported at the ends. I think the adhesion in relation to shear is not as important and I think the cross-sectional shear can be taken higher than in the beam; I should say it could be taken at two to three times as much, and it seems to me that the shear on the panel from the center of compression to the center of tension and not the direct punching shear is the important point to consider.

Professor Johnson. — I should have no objection to that, I am sure. The shear, of course, reaches its maximum right near the base of the column. I have not thought very much about figuring the shear in the way Mr. Hogue suggests he would have done in these beams. But I certainly shall, after he has made that suggestion, watch both those points.

A Member. — I would like to ask, when you have a beam with two rows of rods, whether any one would defend placing the rods one above the other in actual contact, and if so, why? What reason would they give for doing it?

Professor Johnson. — I think that is very often done by people under the influence of the Hennebique Company's methods, but I think they are kept in contact only in the middle third or middle fourth of the span and then turned up.

Where they are turned up is toward the end of the span, and where they are together the demand on adhesion is moderate. It seems to me that the question in actual practice, where you find them one on top of the other, is not so important as it would seem at first glance.

The Chairman. — That is to say, you would not recommend placing them in contact where there is a necessity of developing adhesion.

Mr. J. Parker Snow (*by letter*). — The remarks by Mr. Hogue as to the desirability of basing competition bidding on designs furnished by the owners suggests the similarity of the business methods in building reinforced concrete at the present time with that of iron bridge building thirty to thirty-five years ago. At that time the builders of iron bridges made nearly all of the designs, and they pinned their faith in the efficiency of their particular design to some patented feature, either in the form of the truss or some of its component parts, rather than to the weight of metal employed. In this we see a parallelism to the many styles of deformed bars and systems of reinforcement advocated by competitive concrete workers to-day.

Patented forms of structural iron work passed off the stage years ago, and it is quite evident that reinforcing material for concrete is following the same route. Designs for steel bridge and structural work made by the owners are much more common now than in the early days, and the same will be eventually true, without doubt, of designs for reinforced concrete. In the beginning of any type of construction it is natural that owners should wish to throw the responsibility of the design, as well as the construction, on the builder.

In steel construction at the present day it is recognized as good practice to obtain bids by the pound when designs are not furnished by the owners, the sections and details to be submitted later by the builder for criticism and subsequent approval by the owner. A lump sum bid on the builder's design is considered inadvisable. This matter has been studied very thoroughly by the Committee on Iron and Steel Structures of the Railway Maintenance of Way Association, with the conclusion above.

In case of composite structures like reinforced concrete the adaptability of unit price bidding is not quite so simple as in structural steel work; but it seems that a scheme might be devised, and I suggest that the Committee on Concrete and Reinforced Concrete of the American Society of Civil Engineers

be asked to evolve a system of competitive bidding based on unit prices in the absence of designs by the owner.

Lump-sum bids on designs in competition are intrinsically bad. Unit price bidding on the same may lead to excessive sections where no expert is available for checking the designs, but the result is on the side of safety, and the excess of cost is paid by the owner as penalty for his ignorance.

At the meeting on September 26 Mr. Worcester spoke of the necessity of making concrete sills deep enough below the surface of the ground to obtain safety from frost. I have used reinforced concrete beams in a few instances as sills for brick buildings having concrete floors at the ground level without basements. The depth of sill has been a mere assumption on my part. As the buildings that I refer to are boiler houses and the like, that are warm at all times inside, I have considered 3 ft. below the ground level sufficient security against frost. At the same time I endeavored to have the back-filling under and outside of the sills done with cinders or coarse gravel as further protection.

This style of construction is quite economical in the case of brick buildings without basement, built on filled land over marshes, where timber piles are used that must be cut off several feet below the ground surface. If a continuous pile foundation is used, the strength of piling is far in excess of what is needed, and an excessive amount of masonry is required between the pile cut off and the ground line. By grouping piles in piers 16 to 20 ft. apart, and building concrete beams between them for sills on which to start the brick work, ideal conditions are obtained.

The system of construction wherein cast blocks of concrete are used for walls has not been touched upon in this discussion so far as I have observed. It seems to me that a species of this system could be used to advantage where the walls of a building are made up almost wholly of glass, as is the case with the United Shoe Machinery Company's buildings at Beverly for example. Here there are pilaster columns about 16 ft. apart, girders at each floor level and the panel wholly occupied with glass. If the girders had been cast separately beforehand and set when the columns reached the proper height, a considerable reduction in the forms could have been made and some measure of allowance for contraction obtained.

As to the proper consistency for concrete, I think Mr. Wason's claim is just right. Concrete that is wet enough so

that it can be properly mixed and made perfectly compact, that is, without air or water spaces, with reasonable labor contains water enough for complete hydration, which is all we need. By proper mixing I mean so that every side of every particle of the aggregate will be covered with the vehicle. Mr. Larned has well described the difference between good and poor mixing. The materials should be rubbed together. The hoe, if properly used, is a more efficient tool in the latter stage of mixing than the shovel. The analogy with paint mixing is quite pertinent. Most of us know the difference between paint when the dry pigment is simply stirred into the vehicle and when it is ground into the oil. In the case of concrete the aggregate represents the pigment and the vehicle is the moist cement. Citing Mr. Larned's example, a batch of machine-mixed concrete may appear somewhat dry, that is, it looks friable and brittle; with a few more turns of the machine and no addition of water it will appear much more wet. This means that the last turns have plastered all sides of every atom of aggregate with a uniform coat of moist cement. It now has a different color and sheen from what it had before; it looks pasty; it has passed a point analogous to the point of recalescence in highly heated steel; it has come to nature, as old masons say. Concrete will bear many abuses and still be good stuff, but its strength depends in some degree on proper mixing.

The proper packing of concrete has been touched upon. I believe that jarring or quaking is the most efficient. A light rammer set on the surface and rapidly pressed down and raised enough to quake the mass without raising the rammer from contact with the surface is very effective. Our member, Mr. William B. Fuller, calls this "joggling," which perhaps applies best to large masses where rubble plums are used. The object is to get all air and surplus water out of the mass, and a sharp continuous agitation is more effective than blows from a rammer.

[NOTE. — Discussion of this paper is invited, to be received by Fred. Brooks, Secretary, 31 Milk Street, Boston, by September 1, 1907, for publication in a subsequent number of the JOURNAL.]

OBITUARY.

John Eugene Cheney.

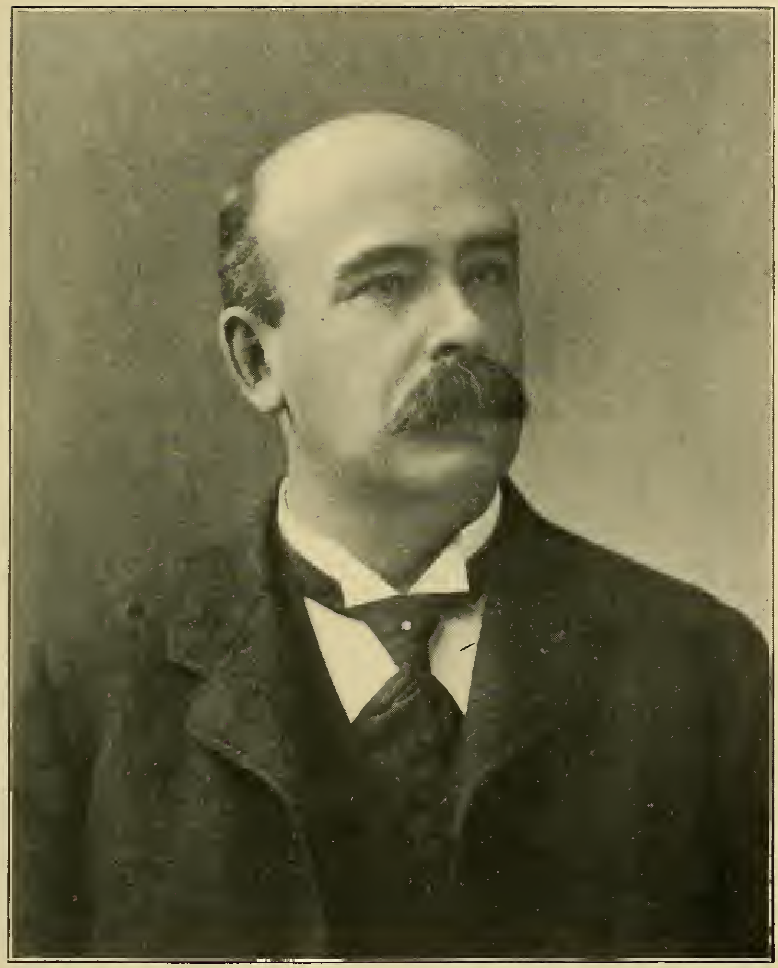
MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

JOHN EUGENE CHENEY was born in Lowell, Mass., February 12, 1847, and was the son of Cynthia Cram and John S. Cheney. His father was a direct descendant of Hannah Dustin. His parents lived originally in the town of Ware, N. H., and removed to Lowell, where for many years his father was superintendent of the Merrimack Mills, and later was engaged in the manufacture of bobbins, spools and shuttles. His father was a prominent and public-spirited citizen, active in promoting the business and educational interests of that city.

Mr. Cheney was graduated from the Lowell High School in 1865, and at once entered the Lawrence Scientific School of Harvard University. He remained there, however, for only one year. The courses at that time in this school extended through but two years, but Mr. Cheney was obliged to leave without completing his course. In recognition of the valuable professional work done by him, however, the university conferred upon him in 1900 the degree of S.B. as of the Class of 1867, and Mr. Cheney prized this degree more highly than if it had been obtained in the usual manner.

After leaving the Lawrence Scientific School Mr. Cheney worked at the Charlestown Navy Yard, and for a time with Mr. E. D. Leavitt, Jr., whose office at that time was in Lowell. In 1870 he went to Louisville, Ky., and entered the employ of the Louisville Bridge and Iron Works, where he remained for four years. Here he obtained the valuable experience which served as the foundation of his future eminence as a structural engineer. He returned to Boston in 1874 to enter the employ of the city as assistant engineer. In 1885 he was appointed assistant city engineer, which position he held until his death, acting frequently as city engineer in the latter's absence. During this period he had charge of the city bridges and he showed himself to be a very capable, conscientious and thorough structural engineer.

The work which Mr. Cheney did was of great value to the city of Boston. In his thirty-two years' service for the city



John Eugene Cheney.

nearly all the city bridges were built or renewed under his supervision, and the bridges which he constructed were well-designed, substantial structures, economically built and appropriate to their surroundings. The retractile drawbridge, a peculiar type of movable bridge possessing certain advantages for low-grade crossings, and of which many examples are to be found about Boston, was developed by Mr. Cheney from a crude and unscientific structure to one scientifically and economically designed, and remains as a distinctive feature of his work. He perfected the wooden-leaf bascule draw and was among the earliest engineers to build bascules in iron. His work in connection with drawbridge machinery and various mechanical plants gained for him a deserved reputation as a mechanical engineer. His experience upon tide-water foundations, built under the peculiar conditions to be found about Boston, was unequaled, and he was long a recognized authority upon foundation work. Among the numerous bridges which he designed and superintended, mention need only be made of the Charlestown Bridge, constructed under the direction of the Transit Commission, and containing the widest draw-span in existence. His crowning work was probably the new Cambridge Bridge, connecting Boston with Cambridge, which with its graceful arches has already taken rank as the most beautiful bridge of its kind in America.

In addition to his work for the city Mr. Cheney's abilities as a structural engineer brought him many commissions from outside parties. For a number of years he was the consulting bridge engineer of the Concord R. R., the Boston, Concord & Montreal R. R., and their successor, the Concord & Montreal R. R., and he designed most of the metal bridges on that system as well as the train-shed at Concord, N. H. He was consulting engineer also for the Connecticut River R. R. and the Massachusetts Central R. R., and in highway bridge work he was consulted by many counties, cities and towns. Indeed, the bridges which he either designed or about which he was consulted are scattered all over New England. He also did much work for architects in the construction of foundations and steel frame buildings. Among such structures in Boston are the Exchange Building, the Exchange Club, the Tremont Building, Tremont Temple, New England Conservatory of Music and the Central Building. A commendable example of mill construction which Mr. Cheney designed is the silverware factory at Concord, N. H., built by the William B. Durgin Company.

Mr. Cheney was early recognized as an engineer of unusual ability and as taking rank with the best structural engineers in this country. He was very careful in his work and took great pains to study his problems carefully, but he never was afraid to adopt a new idea or a form of construction which was novel and untried when once he had satisfied himself that it was proper. His designs were all well thought out, ingenious, economical and well adapted to the circumstances of the case.

Mr. Cheney was married in 1875 to Ellen M. Neal, daughter of the Hon. Peter M. Neal, of Lynn. After returning to Massachusetts he lived in Lynn for ten years, but later moved to Boston, and at the time of his death and for some years previous had lived in the suburb of Brighton. He died suddenly, of heart trouble, September 25, 1906. Mrs. Cheney, a son and a granddaughter survive him. The son, Herbert Neal Cheney, also a graduate of the Lawrence Scientific School, is following his father as an engineer and is at present in the employ of the Boston Consolidated Gas Company.

Mr. Cheney was a member of the Massachusetts Society and Boston Chapter of the Sons of the American Revolution and of the Society of Colonial Wars in Massachusetts. He was also a prominent member of the Boston Society of Civil Engineers and of the American Society of Civil Engineers.

Mr. Cheney was a man of great modesty of character and of a retiring disposition, but was, withal, a man of great force and determination. He was beloved and respected by all who knew him, not only for his high professional acquirements but for his lovable nature and sturdy integrity. He was a man who would never do a mean thing and he was always thoughtful of the rights of others. His memory will long be kept green in the hearts of those who knew him and his death leaves a vacancy in his professional as well as his personal circle which will not soon be filled. Men like him, so strong, so modest, so capable, so thoughtful, so kind, so helpful, are rare indeed.

George F. Swain,
E. D. Leavitt,
Frederic H. Fay,
Committee.

ASSOCIATION
OF
ENGINEERING SOCIETIES.

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PROCEEDINGS.

Engineers' Club of St. Louis.

ST. LOUIS, DECEMBER 5, 1906. — The 624th meeting of the Engineers' Club of St. Louis was held at the Club rooms, 3817 Olive Street, Wednesday evening, December 5, 1906. President Layman presided. Fifteen members and one guest were present.

The minutes of the 623d meeting were read and approved and the minutes of the 414th meeting of the Executive Committee were read.

President Layman presented the report of the Executive Committee for the year just ended and showed an attendance chart of members and visitors. Upon motion this report was received and filed.

Secretary Fernald's report was then read and, upon motion, received and filed.

Treasurer Wall's report was read. Mr. Brenneke moved that the report be received and filed and the accounts audited by a special accountant at the expense of the Club. Motion seconded and carried. Librarian Fernald's report was read, received and filed.

The following committee reports were then read, received and filed:

Report of Committee on Extension of Membership. Mr. W. H. Bryan, Chairman.

Report of Committee on United States Fuel Testing Plant, Mr. Edward Flad, Chairman.

Report of Committee on Regulation of Construction of Reinforced Concrete in St. Louis, Mr. Hans C. Toensfeldt, Chairman.

The report of the Board of Managers of the Association of Engineering Societies, Mr. Hans C. Toensfeldt and Mr. A. P. Greensfelder, was read, received and filed.

Applications for membership were presented from: Harold R. Wilson, Chas. K. Traber, Maurice B. Peuguet, Frank Johnson Trelease, Oscar Guy Selden, Howard Warren Hall.

The report of the Nominating Committee for officers for the ensuing year was then read and additional nominations called for. No further nominations were made, however.

Mr. Brenneke moved that all applicants be invited to attend the next meeting of the Club at the Annual Dinner on the same basis as members of the Club. Seconded and carried.

Adjourned.

A. P. GREENSFELDER, *Secretary, pro tem.*

St. Louis, December 19, 1906. — (Annual Dinner, Mercantile Club.) The 625th meeting of the Engineers' Club of St. Louis was held at the Mercantile Club, Wednesday evening, December 19, 1906, at 8 P.M. Thirty-one members and eleven guests were present. President Layman presided.

After an enjoyable dinner the following toasts were responded to: W. A. Layman, "Retiring President's Address"; John A. Laird, "Gas — and More Gas"; Harry B. Hawes, "14 Feet Through the Valley"; A. S. Langsdorf, "Engineering Education"; W. S. Eames, "Skylines"; Rabbi Leon Harrison, "The Men Who Do Things"; R. S. Colnon, "Engineering Without Specifications."

Adjourned.

R. H. Fernald, *Secretary.*

Civil Engineers' Society of St. Paul.

St. Paul, Minn., January 14, 1907. — The twenty-fourth annual meeting of the Civil Engineers' Society of St. Paul was held at the Merchants' Hotel at 6.30 P.M.

Fourteen members and two visitors in attendance and President Claussen in the chair.

Minutes of previous meeting were read and approved.

After a few introductory remarks the President called for the annual reports of the officers of the Society, and the reports of the Secretary, Treasurer, Librarian and Auditor of 1905 accounts were read, received and ordered filed.

The Librarian was authorized to publish a classified catalogue of books and periodicals in the Society library, and Mr. J. B. Irvine volunteered to assist the Librarian in the preparation of the work.

Mr. Starkey and Mr. Heuston were appointed to audit the 1906 accounts.

The Treasurer was authorized to draw a check in favor of John W. Cramsie for care of the Society room at the Court House.

The resignation of Mr. S. B. Williamson was accepted.

The following resolutions were passed:

Resolved, That the Civil Engineers' Society of St. Paul express their gratitude by a vote of thanks to the Hon. F. C. Stevens for his gift to the Society of forty-seven volumes of Government Reports.

Resolved, That the Civil Engineers' Society of St. Paul extend their thanks to the authors, Charles B. Breed and George L. Hosmer, for the gift of their book "Principles and Practice of Surveying."

Mr. Claussen positively refusing to accept the presidency for another term, Mr. L. W. Rundlett was duly elected by ballot.

The Secretary was instructed to cast the ballot of the members present for J. Henry Fitz as Vice-President, and successively for the reëlection of the present incumbents of the remaining offices after his own reëlection in a similar way. The list of officers for the year 1907 is consequently:

President — L. W. Rundlett.
Vice-President — J. Henry Fitz.
Secretary — C. L. Annan.
Treasurer — L. P. Wolff.
Librarian — G. Z. Heuston.

Representative on the Board of Managers of the Association of Engineering Societies — A. R. Starkey.

At 7.30 the meeting was adjourned to the dining room.

After dinner the company were held closely interested until 10.30 by the responses of the following gentlemen, Mr. Claussen acting as chairman:

Mr. J. D. Du Shane spoke of the urgent necessity for the improvement of water ways.

Mr. G. O. House explained the detail of district steam heating.

Mr. Oliver Crosby told of his late trip to the Panama Canal and discussed specialized engineering.

Mr. G. W. Cooley, state engineer, gave much information in a most entertaining manner concerning good roads.

Prof. W. R. Hoag enlarged on the specialty of railroad engineering.

C. L. Annan, *Secretary.*

Montana Society of Engineers.

Butte, Mont., December 8, 1906. — The regular meeting of the Society for December was called to order by President Dunshee at 8 p.m., in the Society Room, No. 16 Leyson Block.

More than the usual number of members were present. The minutes of the last meeting were approved as read. The application for membership of Arthur Vincent Corry was read, approved and the ballots ordered mailed to voting members. Fred J. Brule was elected to membership by a unanimous vote. An exchange of courtesies in the use of library and society room, requested by the Engineering Society of Rochester, N. Y., was approved and the Secretary was instructed to reply to the request affirmatively.

The following resolutions on the death of Charles W Leimer were presented:

Whereas, In a far-away country, beneath the cliffs of the Andes, remote from countrymen, kindred and human succor, Nature, in one of her most savage moods, brought the brilliant career of Charles William Leimer to a tragic end, and

Whereas, It is but fitting that the members of this Society should express their appreciation of his brilliant career in the field of scientific endeavor, his unselfish devotion to those for whom he toiled, his unfailing success in the solution of all problems submitted to him, his achievements in foreign lands where methods were crude and materials lacking, his youthful enthusiasm wherever he toiled and triumphed, his ready response to all who sought his words of cheer and deeds of charity; therefore be it

Resolved, That this Society cherish the memory of the achievements of him who was one of its most youthful members and rejoice that it has been permitted that his reputation and career should become a part of the history of the Montana Society of Engineers. And be it

Resolved, That these resolutions be placed upon the records of this Society, and a copy of the same be sent to the family bereft.

Approved.

R. K. Humphrey,
C. W. Goodale,
C. H. Moore,
Committee.

An informal talk about plans for the approaching annual meeting was had, after which the Society adjourned.

Clinton H. Moore, *Secretary.*

Technical Society of the Pacific Coast.

San Francisco, December 7, 1906. — Regular meeting called to order at 8.30 o'clock p.m., by Prof. C. B. Wing.

The minutes of the last regular meeting were read and approved.

The following Nominating Committee was elected by the members present to select a ticket of officers for the ensuing year: Past President Marsden Manson and Messrs. A. Ballantyne, Loren E. Hunt, Adolf Lietz and Morton L. Tower.

The Secretary was instructed to notify these members of their election.

The following papers were read and discussed:

1. " The Long Beach Hotel Accident," by Lewis A. Hicks, followed by

2. Mr. M. C. Couchot, who read some notes on the " Most Effective and Economic Methods of Reënforced Concrete Construction," and who discussed the paper just read by Mr. Hicks.

3. " The Mechanics of Reënforced Concrete," by Prof. C. B. Wing.

4. Discussion of the subject by Prof. C. Derleth, Jr., after which a general discussion took place, in which many of the members took an active part.

A paper by Mr. James C. Bennett on a similar subject was laid over to be read at the next regular meeting of the Society.

Upon motion, a vote of thanks was tendered to the authors for their valuable contributions to this branch of structural engineering, for whose wide application there appears to be an opportunity in the rehabilitation of the city of San Francisco.

Meeting adjourned.

Otto von Geldern, *Secretary.*

Association of Engineering Societies.

Vol. XXXVIII. FEBRUARY, 1907. No. 2.

PROCEEDINGS.

Engineers' Club of St. Louis.

St. Louis, January 2, 1907. — The 626th meeting of the Engineers' Club of St. Louis was held at the Club Rooms, 3817 Olive Street, Wednesday evening, January 2, 1907. President Fish presided. Twenty-nine members and twelve guests were present.

The minutes of the 624th and of the 625th meetings were read and approved. The minutes of the 415th meeting of the Executive Committee were read.

The following applications for membership in the Club were submitted:

Louis N. Beals (member), W. L. Greene (member), Wm. Arthur Ruggles (member).

The following were elected to membership in the Club: Members: August Emanuel Bjork, Daniel Breck, Maurice B. Peuguet, Francis E. Schwentler, Chas. K. Traber, Harold R. Wilson. Associate Members: Howard Warren Hall, Oscar Guy Selden. Juniors: Eugene Tritle Spencer, Frank Johnson Trelease.

A very interesting and instructive paper was presented by Mr. Carl Gaylor, entitled "Reinforced Concrete: Its Limitations." A lively discussion followed the reading of the paper, in which Messrs. H. C. Toensfeldt, von Maur, Colby, Moreno, Layman, Viterbo, Fernald, Brenneke, Bruner and Merton participated.

Adjourned.

R. H. Fernald, *Secretary.*

St. Louis, January 16, 1907. — The 627th meeting of the Engineers' Club of St. Louis was held at the Club Rooms, 3817 Olive Street, Wednesday evening, January 16, 1907. Vice-President Brenneke presided. Thirty-eight members and twenty guests were present.

The minutes of the 626th meeting were read and approved and the minutes of the 415th meeting of the Executive Committee were read.

The following applications for membership were presented: Claude A. Bulkeley and Philip Florreich, Jr.

The discussion of the evening upon "Rapid Transit Facilities for St. Louis — Subway? Elevated?" was exceedingly interested and spirited.

Mr. Robert Moore, who was expected to open the discussion, was unable to be present on account of illness. The Secretary read a note from

him, which concluded as follows: " I am more than sorry not to be able to be present at the meeting, as I should like very much to hear the discussion and to add my word in favor of a subway or subways, located and, at the proper time, built with the sole view to the greatest possible public service."

Professor Van Ornum recommended three systems of surface lines, one northward along the river, one southward along the river and one westward. The question of elevated roads or subways would, in his opinion, apply only to the radial lines rather than to the north, south and west lines. As a matter of construction he regards subways as better in form than elevated roads. One of the serious questions to be considered is the arrangements of terminals and loops in the business portion of the city. One difficulty which he said had to be overcome is due to the fact that the city has permitted many building owners to extend their basements to the curb.

Mr. Albert T. Perkins, of the Terminal Railroad Commission, persented charts showing the relative number of trips made and the number of passengers carried in the city for the past eighteen years. His figures showed that the number of trips made by the transit lines is the same to-day as fifteen years ago, whereas the number of passengers carried has doubled during that period. From 60 000 000 passengers handled in 1889, he said that passenger traffic upon the street car systems of St. Louis had increased to 207 000 000 in 1906. The apparent lack of increase in the number of trips has, to some extent, been counteracted by the various consolidations from time to time, with the consequent lengthening of trips and also the increased car capacity. He emphasized the fact that the rapid increase in business in the city will necessitate increased rapid transit accommodations. He also called attention to the fact that people are moving from the more dense sections. In speaking of the relative merits of subways and elevated roads he mentioned incidentally that in Boston and New York four steps less are required to get down to the subway than up to the elevated. Subways cost four times as much as elevated roads.

Boston Subway cost $2 500 000 per mile.
New York Subway cost $2 150 000 per mile.
New York Elevated cost $500 000 per mile.
New York surface lines overhead construction cost $50 000 per mile.
New York surface lines conduit construction cost $150 000 per mile.

Mr. Perkins stated that if subways were built he felt that they should be built by the city and then leased to the company operating the surface lines.

The charts presented by Mr. Perkins brought forth criticism from Captain Robert McCulloch, general manager of the United Railways Company, and from Mr. John I. Beggs, president of the North American Company. Both contended that there has been a great increase in the number of miles traveled per trip during the period mentioned and that the charts should have been constructed upon that basis. Captain McCulloch emphasized the fact that during the World's Fair every effort was made to run the cars for the benefit of the people and the good reputation of the city. He stated that the cars ran full in one direction but empty on the return, and that in spite of the great volume of business

the increase in operating expense, etc., was so heavy that the proposition did not pay financially.

Mr. M. L. Holman stated that St. Louis is not hampered like Boston and New York, but has the whole state west of it in which to grow. The city is rapidly growing westward and we have no right to restrict this growth by building subways, etc., in such localities that they will prohibit this natural development. At the present time we have about all the facilities that are needed. He expressed his appreciation of the fact that the cars must necessarily be more or less crowded during the rush hours, as it is impossible to pay interest on the capital invested if cars enough are used to carry everybody comfortably one way in the morning and the other way at night. He further stated that there are two natural outlets for transportation to outlying districts, one through Mill Creek Valley and the other near Portland Place and other fashionable districts in the West End, which, in spite of the present agitation, would probably have to be sacrificed finally in the interests of the problem.

Mr. H. J. Pfeifer said that if an elevated were erected he felt that the proper place for it was along the right of way of the present Suburban Road. He suggested an elevated as far east as Vandeventer or Grand Avenue and then a depression of the tracks to a subway, which probably would continue as far east as Twelfth Street or possibly Eighth, with several loops in the downtown district not on the same grade.

Mr. John I. Beggs feels that elevated roads are antique and even becoming obsolete and that a subway is the proper form for St. Louis. He pointed out the physical and financial difficulties to be overcome and that it would be practically impossible to build a subway in less than five years. If the people of St. Louis get a system of subways in ten years they may be thankful. Realizing that subways in New York cost over $2 000 000 a mile, and that the cost of such construction is increasing, he pointed out that the financing of such a proposition will take considerable time. The restrictions thrown about corporate interests by the laws of Missouri, forbidding capitalization beyond a certain figure, make the problem even more difficult. In referring again to the charts presented by Mr. Perkins, he called attention to the fact that it would be found that the total mileage had increased in proportion to the passengers carried. He stated that both the total mileage and the length of trips had been increasing. He believes that the city should construct a subway and then lease it to some company. In defending criticism of the present service on the suburban line he stated that either fifteen or seventeen more cars were running to-day on the suburban than were ever run by the Suburban Company itself, including extra trippers and all.

Mr. Wm. Bouton stated that what the people desired was the ability to get to outlying districts or to get from one part of the city to another without being obliged to go way down town and then out again. He said that the ideal condition was not to take you from where you live, down town, but to pick you up where you happen to be and put you where you want to go.

Mr. W. A. Layman pointed out that there is a close relation between the Terminal Railway situation and other transportation problems. The terminals cannot handle the freight of the city now and the city cannot spread out until the terminals can do this. He stated that the

public must decide what it wants in the way of facilities and also whether the public desires monoplies to carry out the plans.

Mr. H. L. Rohwer said that the population must increase with the business growth of the city. This means rapid transit. He believed an elevated line could be run from the Suburban right of way; but inside of the city, there is only one opinion — must have subways. How far east these should go is a question. Passenger subways should take precedence over freight.

Mr. A. P. Greensfelder suggested the passenger mile and the train mile as the proper units for laying out the charts presented by Mr. Perkins. Mr. Perkins defended the criticism of his charts on the ground that they were made from the figures that are available and that no other figures were at hand.

Mr. S. Bent Russell said that he felt that the present management of our transit lines was undoubtedly as good as that of any city in the country. He stated that he had lived in St. Louis a great many years and that the cars were no more crowded now than they used to be — because they couldn't be.

Adjourned.

R. H. Fernald, *Secretary.*

Civil Engineers' Club of Cleveland.

On the evening of January 11 the new rooms of the Club, No. 718 Caxton Building, were dedicated by a reception, attended by about 150 members of the associated clubs, and ladies. Short talks by the President, Mr. Warner, Mr. Paul, Mr. Bernard L. Green, Mr. N. P. Bowler, Mr. F. C. Osborn and others were followed by the serving of refreshments, after which the floor was cleared for dancing.

Joe. C. Beardsley, *Secretary.*

Regular Meeting at the new rooms, 718 Caxton Building, January 15, 1907, called to order by the Vice-President at 8.20 p.m. Present, 30 members and 14 visitors.

Mr. Wright, as presiding officer, very fittingly commented on the confortable amd pleasant quarters the Club has secured and highly complimented the work of Secretary Beardsley in bringing about this agreeable change.

Minutes of the preceding meeting read and approved.

Applications for active membership of Lester A. Fauver and Theodore John Tellefsen, approved by the Executive Board, were read.

The tellers, Messrs. Horner and J. E. A. Moore, reported the election to active membership of Clarence W. Courtney.

A Nominating committee, to select nominees for officers for the ensuing year, consisting of the following members, was elected: Burrows, Frazier, Herman, Honsberg, McKee, Ray and Palmer. As there were only seven nominations for this committee, on motion of Mr. Lane, seconded by Mr. Horner, the Secretary was instructed to cast the ballot for these nominees.

Mr. Harry Y. Norwood, of the Hohmann and Maurer Manufacturing Company, Rochester, N. Y., presented a very instructive and interesting

paper on "Thermometry and Temperature Regulation," illustrated by lantern slides.

Adjourned.

(Signed) DAVID GAEHR, *Acting Secretary.*

A SEMI-MONTHLY meeting of the Club was held on the evening of January 29, 1907, at which Mr. Walter B. Snow, of B. F. Sturtevant Company, Boston, Mass., gave an interesting account of the removal and rebuilding of their plant at Hyde Park, near Boston. The paper was illustrated with many lantern slides. There was an attendance of about 100 members and guests.

On motion of Mr. Osborn, a vote of thanks was tendered the speaker.

JOE. C. BEARDSLEY, *Secretary.*

Montana Society of Engineers.

TWENTIETH ANNUAL MEETING, JANUARY 10, 11, 12, 1907. THURSDAY.— The day was devoted to an inspection of the Washoe Reduction Works at Anaconda, Mont. About 25 members left Butte on the morning train, and on their arrival at Anaconda were met by several officials of the Washoe Company and escorted to the Montana Hotel, where they enjoyed the hospitality of the Anaconda Club till after lunch. A special car took the party to the smelter where, under the guidance of Messrs. Mathewson, Wraith, Whyte, Repath and Jenney a trip was made through the various departments of the plant and every opportunity was given for a thorough inspection of the same, which brought great pleasure to the visitors. Late in the afternoon a visit was made to the brick department of the A. C. M. Co., where special pains were taken to explain the workings of that concern, both as to materials and methods. Dinner at the Montana Hotel completed the labors and pleasures of the day, and during the evening the visiting members enjoyed the hospitality of the Butte members at the Silver Bow Club.

FRIDAY.— The forenoon was made pleasant by a visit to the Montana State School of Mines. President Bowman and the faculty placed the visitors under obligations to them for the very cordial welcome extended, and the hour of departure came far too soon for the parting guests. Superintendent Wharton, of the Butte Street Railway, placed a special car at the disposal of his brother members, and early in the afternoon a trip was made to the B. & M. Co.'s plant at Meaderville. There the visitors were shown through the surface plant by Superintendent Adams and Master Mechanic Brule, and all modern improvements taken into account. A trip through the Leonard mine afforded an attractive shelter to all partakers thereof, though a fearful snowstorm raged "on top." On the way back to town a call was made at "The Street Car Barn," and many objects of interest were there seen. "A Dutch lunch" was the only entertainment of the evening.

SATURDAY.— The business session of the Society was called to order in Judge Lynch's court room at 10 A.M., with President Dunshee in the chair. The minutes of the last meeting were read and approved. The Secretary presented the applications for membership in the Society of Messrs.

Ring, Lindsay, McRae, Potter and Lewis, and after approval the necessary ballots were ordered to be sent out. Arthur Vincent Corry was elected to membership by a unanimous vote. The Secretary presented the ballots for the officers elect. and Tellers Whyte and Griggs counted the same and reported 43 ballots. straight. Thereupon President Dunshee declared the following officers elected for the ensuing year: President, E. C. Kinney, first vice-president, Archer E. Wheeler; second vice-president, Arthur H. Wethey; secretary and librarian, Clinton H. Moore; treasurer and member of the Board of Managers of the Association of Engineering Societies, Samuel Barker, Jr.; trustee for three years, Azelle E. Hobart. President Dunshee retiring, President-elect Kinney commenced the duties of his office by making a short speech of acceptance. The annual reports of the secretary and treasurer were then read and referred to the Trustees. The Committee on Resolutions on the death of the late Geo. H. Robinson presented the following, which were read by the secretary;

Resolutions on the Death of George H. Robinson.

Whereas, Almighty God has removed, by death, our brother member, George H. Robinson; and,

Whereas, It is fit that the members of this Society should express their appreciation of his remarkable talents and marked originality in the field of mining engineering; therefore be it

Resolved, That this Society has, in the death of George H. Robinson, lost one of its most brilliant and talented members, and that a sense of personal loss is keenly felt by every member who knew him well; and be it

Resolved, That a copy of these resolutions be spread upon the records of this Society, and a copy of same be sent to his bereaved family.

Frank L. Sizer,
William F. Word,
Albert S. Hovey,
Committee.

The resignation of Horace V. Winchell was read and the Secretary was instructed to invite him to become a corresponding member instead. Various letters of regret from absent members were read. A communication from President Bowman, of the State School of Mines, was next in order, having for its object the establishment of a Montana Geological Survey by legislative enactment. After discussion, the paper was referred to the Trustees, with instructions that they present a report on the same at the next monthly meeting of the Society. The Secretary of the Society presented the needs of a new membership list, and a compilation of the Constitution and By-Laws in a more attractive form, and after considerable discussion a resolution was adopted instructing the Secretary to publish a new list of members, with Constitution and By-Laws.

A vote of thanks was extended to all who have contributed to the success of the annual session, and the Secretary was instructed to convey the same to all parties concerned.

President Kinney called Mr. McArthur to the chair, and then made a short talk on the subject of a state irrigation law, urging the members to render their assistance in having the present bill passed, now pending in the Montana Legislature. The Secretary read the program for the afternoon and adjournment followed.

The afternoon session began at 2 P.M., President Kinney presiding. The address of the retiring President, B. H. Dunshee, was much enjoyed by all the members and an appreciative audience. Professor A. N. Winchell, of the State School of Mines, gave a very interesting account of some experiments on the genesis of copper ores, and Professor Geo. W. Craven, of the State School of Mines, presented a scholarly thesis on "Concrete" and its practical uses. A short discussion closed the exercises of the afternoon. The usual banquet completed the actual work of the annual session.

Clinton H. Moore, *Secretary.*

Technical Society of the Pacific Coast.

Regular Meeting held January 4, 1907, called to order by Vice-President Franklin Riffle. The minutes of the last regular meeting were read and approved.

The Nominating Committee appointed at the last regular meeting submitted the following selection of officers for the ensuing year:

For President — Franklin Riffle.
For Vice-President — H. D. Connick.
For Secretary — Otto von Geldern.
For Treasurer — E. T. Schild.
For Directors — Hermann Barth, Edward F. Haas, Hermann Kower, Carl Uhlig and C. B. Wing.

(Signed by the chairman of the committee), Marsden Manson.

The report was ordered received, the committee discharged and the Secretary instructed to prepare the ballots for the annual meeting.

Mr. Marsden Manson read a paper entitled "The Struggle for Water in the Great Cities of the United States," the discussion of which was postponed until the annual meeting, January 18.

The Secretary was instructed to notify the members that the paper would be brought up again on that evening.

The meeting thereupon adjourned.

Otto von Geldern, *Secretary.*

Annual Meeting, called to order January 18, 1907, at 8.30 P.M., by Vice-President Franklin Riffle.

The minutes of the last regular meeting of January 4, 1907, were read, and upon motion duly approved.

The Secretary stated that a report of the Society's work during the severe times after the catastrophe had been rendered recently and that it had been published in full in the Journal of the Association of Engineering Societies, No. 299, September, 1906, and circulated to every member and friend of the Technical Society, to show him what had been accomplished in other lines when it was impossible to take up professional matters in the usual way. The Secretary reported that the Society had still 166 active members on its list, a copy of which he laid before the meeting.

The Treasurer thereupon submitted his report, as follows:

He stated that, owing to the loss of all the records of the Technical Society (the fire having destroyed the bank and check books of the treasurer, the receipt book and vouchers of the secretary and the memorandum book of the collector), it was not possible for him to make his account a detailed or itemized one.

Receipts and expenditures were submitted, but the balance in the hands of the Treasurer on the evening of the annual meeting, amounting to $703, must be accepted by the Society without further proof.

He submitted also a list of the standing of the members on January 1, 1907.

On motion, the report of the Treasurer was ordered received, and the balance of $703 in the treasury on January 18, 1907, approved as correct, with the instruction that the report be spread in full upon the minutes.

The tellers appointed to open and count the ballots for the annual election reported that forty-two votes had been cast and that the votes were unanimous for the following officers and directors:

President — Franklin Riffle, civil engineer.
Vice President — H. D. Connick, civil engineer.
Secretary — Otto von Geldern, civil engineer.
Treasurer — E. T. Schild, manufacturer.
Directors — Hermann Barth, architect; Edward F. Haas, civil engineer; Hermann Kower, university professor; Carl Uhlig, civil engineer; Charles B. Wing, university professor.

The chairman thereupon declared these officers duly elected to serve the Society during the coming year, and he expressed the hope that the year would be a prosperous one for all concerned.

Mr. Manson moved that the Board of Directors be authorized to ascertain in what manner a certain sum of money, not to exceed one third of the amount in the treasury, could be spent to advantage in furthering the interests of the Technical Society; that is, that it in some measure identify itself with the great work of rehabilitation of the city of San Francisco by special investigations or collection of engineering data. This motion was carried.

The paper by Mr. Marsden Manson on the "Struggle for Water in the Great Cities of the United States" was read again by the author and discussed by Mr. Luther Wagoner, Mr. Michael Casey, Mr. Hermann Barth and others.

The meeting thereupon adjourned.

Otto von Geldern, *Secretary.*

Louisiana Engineering Society.

New Orleans, La., January 12, 1907. — Annual meeting of the Louisiana Engineering Society The meeting was called to order at 8.30 p.m. by President Hoffman, with about thirty members present.

The minutes of the previous meeting were read and approved.

The Secretary then read the Board of Direction's annual report, including the reports of the Secretary, Treasurer, Library Committee,

Auditing Committee and Outing Committee. On motion of Mr. Coleman the reports were ordered received. After discussion by various members, the following resolutions were adopted on motion of Mr. Coleman:

A resolution approving the recommendations of the Library Committee and instructing the new Board of Direction to carry them into effect; a resolution that the other recommendations of the Board of Direction be referred to the new board for study and for proper presentation to the Society.

The Chair then appointed Messrs. Theard, Duval and Zander as tellers to open and count the ballots on the vote for officers to serve during 1907. Mr. Theard, as chairman, reported that the following officers had been elected:

President — G. W. Lawes.
Vice-President — C. W. Wood.
Secretary — L. C. Datz.
Treasurer — James C. Haugh.
Member Board of Direction — John Riess.
Member Board of Association of Engineering Societies — Walter H. Hoffman.

Mr. G. W. Lawes was then escorted to the president's chair, and that gentleman in a few appropriate words thanked the members for having conferred upon him the honor of electing him to the presidency.

Mr. Walter H. Hoffman then read his annual address as retiring president. Mr. Hoffman's few words were received with applause.

President Lawes next introduced Gen. Arsene Perrilliat, who desired to say a few things in regard to the transforming of this Society into an engineer's club. General Perrilliat's idea was to the effect that the social feature should be added to the meetings of the Society and that lunches, drinks and the like should be obtainable at the rooms of the Society. His purpose is to bring the members closer together than is possible under the existing system. General Perrilliat's remarks brought about some discussion, at the end of which the following resolution was adopted on motion of General Perrilliat:

Resolved, That the President appoint three members to form a committee; said committee to meet and study a project by which this Society could be changed into an engineers' club, where the social feature will be added to the purely technical feature, and said committee to report back to the Society.

The Society then adjourned to the Old Hickory, where the annual banquet was held.

Marcel Garsaud, *Secretary.*

Boston Society of Civil Engineers.

Boston, December 19, 1906. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.55 o'clock p.m., President F. W. Hodgdon in the chair; sixty-nine members and visitors present.

The record of the last meeting was read and approved.

Messrs. John K. Barker, Edward Burr, Wilbur W. Davis, Burton I. Drisko, Harry W. Fitts, Edward Holmes, Elbert E. Lochridge, Thomas MacKellar, Leslie W. Millar, Thomas E. Penard, John J. Rourke and John A. Starr were elected members of the Society.

Mr. Leonard Metcalf, for the committee appointed to prepare a memoir of Freeman C. Coffin, a vice-president of the Society, presented and read its report.

On motion of Mr. W. S. Johnson it was voted to postpone indefinitely the election of a vice-president to fill the vacancy caused by the death of Freeman C. Coffin.

The President brought to the attention of members the desirability of addressing an appeal to the Massachusetts delegation in the national House of Representatives, urging them to petition the Speaker, without delay, that the bill now pending which provides for the establishment of the Southern Appalachian and White Mountain Forest Reserves, may be taken up for final action and passed at an early day in the present session. After a short discussion it was voted to refer the matter to the Board of Government, with the suggestion that a delegation be selected to write to the members of Congress from this state urging the early consideration of the bill.

Mr. Paul Winsor, chief engineer of motive power and rolling stock, Boston Elevated Railway Company, was then introduced and gave a very interesting talk on "Gas Engines and Producer Plants as Used by the Boston Elevated Railway Company."

A discussion followed, which was participated in by Mr. E. L. Clark, of the Westinghouse Machine Company; Mr. H. W. True, of the Barbour-Stockwell Company; Mr. J. C. Riley, of the Massachusetts Institute of Technology, and others.

After passing a vote of thanks to Mr. Winsor for his interesting talk, the Society adjourned.

S. E. TINKHAM, *Secretary.*

BOSTON, JANUARY 23, 1907. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 8 o'clock P.M., President F. W. Hodgdon in the chair; fifty-eight members and visitors present.

The record of the last meeting was read and approved.

Messrs. Benjamin Fox, George F. Hooker and Leonard C. Robinson were elected members of the Society.

On motion duly seconded the President was requested to appoint a committee of three to report to the meeting the names of five members to serve as a committee to nominate officers for the ensuing year. The President appointed as this committee Messrs. C. F. Allen, H. B. Wood and N. S. Brock. Later in the evening this committee reported the following names as members of the Nominating Committee, and they were unanimously elected: Messrs. Frederick Brooks, Ira N. Hollis, George A. Carpenter, Frederick H. Fay and Charles B. Breed.

On motion of Mr. Adams the usual committee (Mr. Henry Manley) was appointed to make arrangements for the annual dinner.

Prof. Dwight Porter offered the following resolution, and it was unanimously adopted:

It having come to the attention of the Boston Society of Civil Engineers that during the last session of Congress a reduction of $50 000 was made in the appropriation in the Sundry Civil Bill for the work of the United States Geological Survey in gaging the streams and otherwise investigating the water resources of the United States, the Society views with apprehension this reduction in the appropriation for a work which it believes to be of great importance in the material development of the country.

Realizing that it is impracticable under state or private organization alone to carry on work of the scope that is necessary, it believes it to be for the best interest of all that the investigations should be made under national supervision.

The water resources of New England are of the utmost importance to her industrial welfare, and the present reduction in the appropriation for measuring those resources is believed to threaten the continuity of records upon which the economic development of the streams must depend.

It is, therefore, the sense of the Society that immediate restoration of the appropriation should be made to its recent amount, and that consideration should be given by Congress to the necessity of increasing the amount still further in the near future; and it is hereby resolved that the Board of Government of the Society be directed to forward copies of this resolution to each member of Congress from New England.

In the absence of the author, Mr. H. K. Higgins, the Secretary read a paper entitled " Replacement of Bridges and Allied Structures." The Secretary also read discussions prepared by Messrs. J. P. Snow and J. R. Worcester.

The discussion was continued by Messrs. Swain, McKibben, Guppy, Fay, Cowles, Manley and others.

Adjourned.

S. E. Tinkham, *Secretary.*

Sanitary Section.

Boston, January 9, 1907. — A special meeting of the Sanitary Section was held at the Copley Square Hotel, forty-three members and guests being present.

Mr. L. D. Thorp, for the committee appointed at the last meeting to prepare a memorial to the late Freeman C. Coffin, reported progress.

The following resolutions were adopted by the Section:

Whereas, Death has removed our late chairman, Freeman C. Coffin, and we, the members of the Sanitary Section of the Boston Society of Civil Engineers, do sincerely mourn our loss; and

Whereas, He was not only our leader, but chief among us in service and devotion; and

Whereas, To him was due not only the conception of the idea which was the basis for the organization of this Sanitary Section, but also much of the energy which brought it into being,

Be it Resolved, That we, the members of the Sanitary Section of the Boston Society of Civil Engineers, hereby express our sense of loss and our love for our friend and colleague;

Be it Resolved, That we do hereby express our sympathy for the family of our late chairman;

Be it Resolved, That these resolutions be spread upon the records of the Society, and that a copy be sent to the wife and family of the deceased.

Mr. J. C. Chase, for the committee appointed to bring in a nomination for chairman for the unexpired term, reported the name of Leonard Metcalf, and the Secretary was instructed to cast one ballot for Mr. Metcalf.

Mr. M. N. Baker, special agent for the United States Census Bureau, made a few remarks in regard to the schedule for uniform sewerage statistics recently adopted by the Section, urging the general use of this schedule by those having charge of sewerage systems. Mr. Baker stated that the Census Bureau is now publishing municipal statistics from time to time under the heading " Social Statistics of Cities." The Bureau has decided to collect statistics in regard to sewerage and sewage disposal, and there is a prospect that at some time in the near future the agents will be sent into the field and a strenuous attempt made to collect such statistics. To a certain extent, the future action of the Bureau in this respect will be dependent upon the success of the efforts which are now being made by the Sanitary Section. If there is reasonable promise that the statistics exist and can be gathered together, and that the engineers and superintendents in charge will coöperate in the matter, there is little doubt that the Bureau will adopt the schedule prepared by the Section, or a somewhat similar one.

The subject for discussion at the meeting was " The Use of Small Pumping Plants in Connection with Sewerage Systems." The discussion was opened by I. T. Farnham, L. D. Thorp and F. A. Barbour, and was participated in by C. O. Rogers, F. I. Hayes, Bertram Brewer, A. J. Gavett and others.

William S. Johnson, *Clerk.*

Association of Engineering Societies.

Vol. XXXVIII. **MARCH, 1907.** No. 3.

Engineers' Club of St. Louis.

St. Louis, February 6, 1907. — The 628th meeting of the Engineers' Club of St. Louis was held at the Club rooms, 3817 Olive Street, Wednesday evening, February 6, 1907. Vice-president Brenneke presided. Thirty-three members and eighteen visitors were present.

The minutes of the 627th meeting were read and approved.

Applications for membership were presented by Stephen Roy Culbertson (member), Charles Hamilton Fake (member), Walter Robbins (member), Lealon B. Wright (associate member).

The following were elected to membership in the Club: Louis N. Beals, Jr. (member), Claude A. Bulkeley (member), Philip Florreich, Jr. (member), Weeden L. Greene (member), William Arthur Ruggles (member).

The Secretary then reported that Mr. Seth Doan Merton had been transferred at his request from member to associate member.

The subject of the evening was "The New School Buildings of St. Louis."

Mr. Wm. B. Ittner, commissioner of school buildings for St. Louis, reviewed the work of the building department for the past ten years, describing the prevailing type of building in vogue at that time, giving the reasons for the adoption of the present prevailing plan. He stated that the old type of building cost 12 cents per cu. ft. The ventilation in the old buildings was poor. In departing from the old style questions of proper ventilation, lighting, etc., were given serious consideration, as well as other comforts for the pupils. It was decided that to be well lighted a room must be less than 28 ft. wide. A width of 25 ft. was therefore adopted, but in the last few years this has been reduced to 24 ft., with a corresponding length of 32 ft. for each room. Such a room seats 56 pupils. The buildings are not only constructed of excellent material, but a certain amount of attention is given to ornamentation and good taste in design. The buildings are so constructed that sunshine penetrates every part of the building some time during the day. The excellence of construction is shown by the fact that one building which has been up three years has not cost 5 cents for repairs.

The cost of this new type of building is about as follows: Ten years ago one building was put up for 11 cents per cu. ft., one at 12 cents and one at 13 cents. There has been a steady advance in the cost of material and labor, until to-day the cost of such buildings is about 18 cents per

cu. ft. Teachers' College cost 17 cents per cu. ft, and the Clay School, 17.7 cents per cu. ft. This cost of about 18 cents includes all painting, fencing the yard, etc., and everything inside ready for the furniture.

Mr. H. C. Toensfeldt, structural engineer for the department, described the details of construction, dwelling particularly upon the reinforced concrete work.

Mr. C. A. Bulkeley, chief engineer for the department, described at length the heating and ventilating systems. He stated that the allowance was 30 cu. ft. of air per pupil per minute and 50 cu. ft. per minute for adults. Eight changes of air are counted upon per hour in each room. He described the methods of air washing and the general question of humidity. Taking average results from nine schools for four seasons, he stated that the cost of heating and ventilating was 64 cents per 1 000 cu. ft. of space on the basis of 8 hr. per day, 5 days per week.

Mr. Robert Moore expressed the great satisfaction the School Board has felt in the work of the Department of Building. He further stated that the buildings are as fine as in any city of the country, and that they have been secured at as low a cost as any buildings of the same quality.

Adjourned.

R. H. FERNALD, *Secretary.*

ST. LOUIS, FEBRUARY 20, 1907. — The 629th meeting of the Engineers' Club of St. Louis was held at the Club rooms, 3817 Olive Street, Wednesday evening, February 20, 1907. President Fish presided. Forty members and sixteen guests were present.

The minutes of the 628th meeting were read and approved. The minutes of the 417th meeting of the Executive Committee were read.

The following were elected to membership in the Club: Stephen Roy Culbertson, member; Charles Hamilton Fake, member; Walter Robbins, member; Lealon B. Wright, associate member.

The Secretary read two letters relating to positions available and men available for positions.

Col. J. A. Ockerson presented a most interesting illustrated paper upon the Salton Sea. He outlined in detail the many difficulties that had arisen in controlling the waters of this section and the methods adopted in damming and directing the flow of the Colorado River. The discussion by Messrs. Philip N. Moore, Bryan, Merton, Flad, Perkins and Ockerson brought out the essential engineering features connected with this proposition, as well as the relations between certain private corporations, the people of the district, the Southern Pacific Railroad and the government.

Adjourned.

R. H. FERNALD, *Secretary.*

Civil Engineers' Club of Cleveland.

REGULAR MEETING, February 12, 1907, at the Club rooms, called to order by the President, at 8.15 P.M. Present, forty-four members and five visitors.

Minutes of the preceding meeting read and approved.

The application of Sam. W. Emerson for active membership, approved by the Executive Board, was read. The tellers, Messrs. Colegrove and Clifford, reported the election to active membership of Messrs. Lester A. Fauver and Theodore J. Tellefsen.

The Secretary made a brief verbal report of the work of the House Committee, showing that approximately $435 had been spent, to date, on moving to new rooms and furnishing them.

The Nominating Committee reported the following nominations for officers for the ensuing year:

President — Mr. Charles H. Wright.

Vice-President — Mr. Willard B. Beahan.

Secretary — Mr. Joseph C. Beardsley.

Treasurer — Mr. Walter M. Allen.

Librarian — Mr. Joseph R. Poe.

Directors — Mr. George T. Nelles and Mr. Andrew B. Lea.

On motion of Mr. Hawkins, the report was accepted.

It was reported from the Executive Board, that it had been decided to hold the annual meeting at Case School of Applied Science, on the invitation of President Miller.

On motion of Mr. Herman, seconded by Mr. Ritchie, the Executive Board was directed to investigate and report on the feasibility of extending our library facilities.

On motion of Mr. Frazier, the President was requested to appoint a committee to provide for an annual banquet. The President later made the following appointments for this committee: Benjamin, W. M. Allen, Watson, Hopkinson and Carroll.

Mr. Ritchie then read a paper descriptive of the construction of the new 700-ft. dry dock of the American Ship Building Company at Lorain, Ohio, which was discussed by Messrs. Nelles, Hoffmann, Dalgleish, Herman, Hanlon McKee and others.

Adjourned.

JOE. C. BEARDSLEY, *Secretary.*

Boston Society of Civil Engineers.

BOSTON, FEBRUARY 20, 1907. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, Boston, at 8 o'clock P.M. Eighty-eight members and visitors present.

In the absence of the president and the vice-president, Mr. Frederic P. Stearns was elected chairman of the meeting.

The record of the last meeting was read and approved.

Messrs. Theodore W. Norcross and Robert L. Read were elected members of the Society.

On motion of Mr. Street, the thanks of the Society were voted to the Charles R. Gow Company for courtesies extended to members this afternoon on the occasion of a visit to the subway under construction at First Street, Cambridge.

The discussion of the evening on "Engineers' Specifications from the Contractor's Point of View" was opened by Mr. James W. Rollins, Jr. Other members who took part in the discussion were: Messrs. Charles

G. Craib, Charles R. Gow, E. S. Dorr, L. S. Cowles, J. H. Gerrish, E. S. Larned, E. P. Adams and G. T. Sampson. The discussion was closed by Mr. Rollins, who read several letters which he had received bearing on the question.

Adjourned.

S. E. Tinkham, *Secretary.*

Sanitary Section.

Boston, Mass., March 6, 1907. — The annual meeting of the Sanitary Section of the Boston Society of Civil Engineers was held at the Society rooms, Wednesday evening, March 6, 1907, with 31 members present.

The report of the Executive Committee was read by the chairman, and was accepted and placed on file.

The Clerk read a memoir of William W. Burnham, a member of the Section, who died August 11, 1906.

Upon motion of Mr. Sherman it was voted that a committee be appointed by the chair to nominate officers for the ensuing year. The chairman appointed H. P. Eddy, C. W. Sherman and E. W. Branch as members of this committee.

On motion of Mr. Farnham it was voted that a committee be appointed by the chair to oppose the passage of a bill now before the legislature for the extension of civil service laws to heads of municipal departments. Later in the evening this motion was reconsidered, and after considerable discussion it was voted to instruct the chairman to request the Board of Government of the main society to appoint a committee to consider the relation of civil service laws to engineers.

The committee appointed to nominate officers for the ensuing year reported and, in accordance with the instructions of the Section, the Chairman cast one vote for each of the following candidates, who were declared elected.

Chairman — Arthur T. Safford.

Vice-Chairman — Irving T. Farnham.

Clerk — William S. Johnson.

Executive Committee — George A. Carpenter, Lewis D. Thorpe, George E. Bolling.

The paper of the evening was presented by Arthur T. Safford, the subject being "Waste from Lowell Gas Light Company's Yard." The paper was discussed by Messrs. Barnum, H. W. Clark, W. E. McKay, George Bowers and others.

Annual Report of the Executive Committee of the Sanitary Section.

To the Members of the Sanitary Section of the Boston Society of Civil Engineers.

Gentlemen: Your Executive Committee reports with pleasure continued interest and activity in the affairs of the Sanitary Section. During the past year six meetings have been held, with an average attendance of 39 persons, as follows:

March 7, 1906, annual meeting, attendance 70. Papers, "An Account of Several of the Small Sewage Disposal Systems which have been Constructed to Protect the Purity of the Metropolitan Water Supply," by William W. Locke; "The Sewage Disposal Plant at Vassar College," by Ellen M. Richards; "The Sewage Disposal Plant at the State Colony for Insane at Gardner," by J. J. Van Valkenburgh; "The Sewage Disposal Plant of the State Normal School at Hyannis," by George H. Wetherell, Jr.

April 11, 1906, special meeting for the consideration of uniform sewerage statistics.

June 9, 1906, attendance 41. Excursion to the plants of the City Refuse Utilization Company and the New England Sanitary Product Company. Paper, "Modern Methods of Garbage Disposal," by William F. Morse. Dinner at the Point Shirley Club, Winthrop.

October 10, 1906, attendance 42. Paper, "The Relation of the Suspended Matter in Sewage to the Problem of Sewage Disposal," by H. P. Eddy, and A. L. Fales.

December 5, 1906, attendance 38. Paper, "The Maintenance of Sewage Filters in Winter," by G. E. Borden, E. C. Frost and E. R. B. Allardice.

January 9, 1907, attendance 43. Paper, "The Use of Small Pumping Plants in Connection with Sewage System," by I. T. Farnham, Lewis D. Thorpe and F. A. Barbour.

On November 11, 1906, Mr. Freeman C. Coffin, chairman of the Section, died, as previously reported to you. A memoir on Mr. Coffin's life was prepared, and resolutions of sympathy were passed, spread upon the minutes of the Section and sent to Mr. Coffin's family. Mr. Leonard Metcalf was chosen, on January 9, 1907, to fill the vacancy left by Mr. Coffin's death.

The subject of uniform sewerage statistics was carefully considered, and after a full discussion the report of the committee, recommending a form for the presentation of sewerage statistics, was adopted by the Section on June 9, 1906. It seems wise to call to the attention of members the desirability of the adoption, by municipalities and superintendents of sewerage plants, as far as possible, of this form for the presentation of sewerage statistics, in order that the results of operation and maintenance of these works may be as nearly comparable as possible. In this connection we call to your attention a letter written to Mr. M. N. Baker by Mr. L. G. Powers, chief statistician of the Bureau of the Census in the Department of Commerce and Labor, Washington, D. C.

Division of Agriculture.
Department of Commerce and Labor.
Bureau of the Census.

Washington, D. C., February 23, 1907.

Mr. M. N. Baker, Expert Special Agent,
220 Broadway, New York:

Dear Mr. Baker, — Returning from New York on Thursday, I found your letter of the fourteenth instant on my desk, and in accordance with our conversation on this subject, I make formal answer thereto.

As stated in that conversation, it seems to me that the true position of the census with reference to the schedule of the Boston Society of

Engineers is as follows: The census office accepts that schedule tentatively as a basis of future work, and will proceed to make use of the same in the collection of data for its statistical publications so soon as a sufficient number of cities, through their engineering department, adopt that schedule in recording data.

They could further state in their report that the census is at present compiling statistics on sewers and sewage disposal which embody only a few of the most important facts called for by that schedule, and there are great breaks in those statistics owing to the imperfect classification, or want of classification, employed by the various engineering departments of the country.

I herewith return the letter from Mr. Johnson forwarded by you.

With best wishes, I am

Yours very truly,

(Signed) L. G. Powers, *Chief Statistician.*

It is manifest that unless general use is made of the form outlined, the adoption of it by the Bureau of the Census cannot be hoped for, and much valuable information will thus be lost, or at least will remain unavailable to the great majority of those interested in this subject.

The present membership of the Section numbers: members of main society 156; Section members 29; total, 185.

Your Executive Committee bespeaks the active personal interest of every member of the Section in striving to increase the membership and the usefulness of the Section in every way possible. Many superintendents or managers of sewerage systems and sewage disposal plants are not at present enrolled upon the membership of the Section. Some means should be found of reaching these men and of impressing upon them the fact that men who have had practical experience in the operation of such works are particularly welcome, whether of technical attainment or not.

The Executive Committee will welcome suggestions for timely papers or topics for discussion, especially the latter.

Respectfully submitted,

Leonard Metcalf,
For the Executive Committee.

Twenty-fifth Annual Dinner.

The twenty-fifth annual dinner of the Boston Society of Civil Engineers was served at the Hotel Vendome, Boston, Tuesday evening, March 12, 1907, and was attended by 151 members and guests. The usual informal reception was held at 6 o'clock, and the dinner was served at 7 o'clock.

The special guests of the Society were Prof. Frederic R. Hutton, president American Society of Mechanical Engineers; Hon. William Berwin, acting mayor of the City of Boston; Hon. William A. Morse; Mr. Charles F. Knowlton, president Massachusetts Highway Association; Prof. Lucian I. Blake; and Mr. Charles Moore of the Submarine Signal Company. Music was furnished by the Albion Quartet.

At the conclusion of the dinner the President of the Society, Mr. Frank W. Hodgdon, introduced as the first speaker Professor Hutton, who brought the greetings of the American Society of Mechanical Engineers and spoke very interestingly of the new Engineers' Building in

New York City which had been erected through the munificient gift of Mr. Andrew Carnegie. Mr. Morse in an entertaining speech deplored the amount of accusation and ridicule that is now-a-days flung at anybody who has achieved prosperity or prominence. He particularly deplored the tendency to cast reproach upon the legislature of Massachusetts, which he believed at the present day is as good as it ever was, and better than most. Alderman Berwin brought the congratulations of the City of Boston and regretted that his Honor the Mayor was unable to be present. Mr. Charles F. Knowlton spoke particularly of the work of the Highway Association and of the great assistance which the civil engineer was to all who were engaged in the construction of streets.

An interesting incident of the dinner was a report made by Mr. F. P. Stearns of a call made that afternoon on Mr. Henry Manley, who was prevented from attending the dinner because of a slight indisposition. Mr. Stearns said that Mr. Manley for twenty-five successive years had been the Society's committee to arrange the annual dinner, and that on this anniversary it had occurred to some members of the Society to show their appreciation of his services by making him a slight gift. A gold watch and chain had been procured from voluntary contributions from such of the members as could be conveniently reached, and this afternoon the pleasing duty had been assigned him of presenting this gift to Mr. Manley. In accepting the gift Mr. Manley expressed his deep appreciation for the kind remembrance from the members of the Society and would at a later date try to express his feelings in fitting terms.

Boston, March 20, 1907. — The annual meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.50 o'clock P.M., President Frank W. Hodgdon in the chair, 60 members and visitors present. The record of the last meeting was read and approved.

Messrs. Edward Hutchins and Charles F. Knowlton were elected members of the Society.

The President read an invitation extended to this Society by the trustees of the United Engineering Society to participate, through an authorized representative, at the dedication of the building given by Mr. Andrew Carnegie as a home for American Engineering Societies, in New York City, on April 16 and 17, 1907.

On motion of Mr. A. H. French the invitation was accepted and the incoming president was requested to represent the Society at the dedication exercises.

The Secretary read the annual report of the Board of Government and, on motion, it was accepted and placed on file.

The Secretary read his annual report and, on motion, it was accepted and placed on file.

The Treasurer read his annual report and, on motion, it was accepted and placed on file.

Mr. Street presented and read the annual report of the Committee on Excursions. On motion, the report was accepted and placed on file.

The Librarian read the annual report of the Committee on the Library and, on motion, it was accepted and placed on file.

Mr. Johnson presented and read the annual report of the Committee on Advertisements. On motion, it was accepted and placed on file.

Mr. E. W. Howe made a verbal report for the Committee on Quarters.

On motion of Mr. F. P. Stearns the recommendation of the Committee on the Library in relation to the circulation of the books in the Society's library was referred to the Board of Government with full powers.

It was also voted, on motion of Mr. Stearns, to appropriate the sum of $50 for the purchase of standard engineering books.

On motion of Mr. F. L. Fuller it was voted to refer to the Board of Government, with full powers, the appointment of the several special committees of the Society.

President Hodgdon then addressed the Society, giving a very interesting account of some of the difficulties encountered in early surveys of the state of Massachusetts, how they were overcome and the results obtained.

At the conclusion of the President's address the tellers of election, Messrs. Nathan S. Brock and Henry B. Wood, reported the result of the letter ballot and in accordance with their report the following officers were declared elected:

President — Edward W. Howe.
Vice-President (for two years) — Francis W. Dean.
Secretary — S. Everett Tinkham.
Treasurer — William S. Johnson.
Librarian — Frederic I. Winslow.
Director (for two years) — Irving T. Farnham.

Before adjourning the meeting, the President introduced the President-elect, Mr. Howe, who thanked the Society for the great honor conferred upon him.

Adjourned. S. E. Tinkham, Secretary.

Annual Report of the Board of Government for the Year 1906–1907.

Boston, March 20, 1907.

To the Members of the Boston Society of Civil Engineers:

In compliance with the requirements of the constitution, the Board of Government submits its report for the year ending March 20, 1907.

At the last annual meeting the total membership of the Society was 621, of whom 584 were members of the Society, 2 honorary members, 13 associates and 22 were members of the Sanitary Section only.

During the year the Society has lost a total of 20 members; 7 by resignation, 6 by forfeiture for non-payment of dues and 7 have died.

There has been added to the Society during the year a total of 34 members in all grades, 33 by election and 1 transferred from the Toledo Society of Engineers. One of these is an associate and one is a member of the Sanitary Section only.

The present membership of the Society consists of 2 honorary members, 13 associates and 620 members, of whom 20 are members of the Sanitary Section only; making the total membership 635.

The record of deaths during the year is, John J. Howard, died May 18, 1906; Isaac K. Harris, died May 21, 1906; E. Elbert Young, died

June 1, 1906; John E. Cheney, died September 25, 1906; Nelson Spofford, died October 3, 1906, and Freeman C. Coffin, died November 11, 1906. At the time of his death Mr. Coffin was Vice-President of the Society and chairman of the Sanitary Section. William W. Burnham, a member of the Sanitary Section, died August 11, 1906.

Ten regular and one special meetings of the Society have been held during the year, and the Twenty-fifth Annual Dinner was given at the Hotel Vendome on March 12, 1907. The average attendance at the regular meetings was 66, the largest being 106 and the smallest 28. The attendance at the annual dinner was 151.

At the regular meetings the following papers have been read:

March 21, 1906. — Memoir of Dean C. Warren. Address of President John W. Ellis.

April 18, 1906. — Mr. H. A. Miller, "The General Features of the Charles River Basin and Dam." (Illustrated.)

May 16, 1906. — Prof. L. J. Johnson, "Reinforced Concrete Beams." (Illustrated.)

June 20, 1906. — Memoir of William T. Pierce. Prof. F. B. Sanborn, "Fires and their Prevention in Factories." (Illustrated.)

September 19, 1906. — Memoir of E. Elbert Young. General Discussion on Reinforced Concrete Construction.

October 5, 1906. — Continuation of Discussion on Reinforced Concrete Construction.

October 17, 1906. — Mr. Charles Moore, "The Submarine Signal." (Illustrated.)

November 21, 1906. — Mr. F. A. Kummer, "The Development of Wood Pavements." (Illustrated.) Mr. A. L. Plimpton, "Track Work in Washington Street, Boston."

December 19, 1906. — Memoir of Freeman C. Coffin. Mr. Paul Winsor, "Gas Engines and Producer Plants, as used by the Boston Elevated Railway Company."

January 23, 1907. — Mr. H. K. Higgins, "Replacement of Bridges and Allied Structures."

February 20, 1907. — Mr. J. W. Rollins, Jr., "Engineers' Specifications and Contracts from a Contractor's Point of View."

From the report of the Executive Committee of the Sanitary Section it appears that six meetings have been held, with an average attendance of 39. At all of these meetings interesting papers or discussions have been presented, which have been printed in the JOURNAL.

The Society has contributed $45 towards the rent of the hall, and has paid for the use of the stereopticon and for stenographic reports of the meetings, while the other expenses have been met by members of the Section.

At the beginning of the year the treasury was practically empty. The expenses for the preceding three years had been in excess of the income of the Society, the deficiency having been provided for by the balance carried over from previous years. It was plain that this could not continue, and the Board gave the matter immediate attention.

At the annual meeting it was thought that the only solution was either to curtail the expenses of the Society or to increase the income from advertisements inserted in the JOURNAL. If the expenses were decreased,

it would be necessary to curtail some of the work of the Society, and repeated efforts had already been made to increase the amount of advertising in the JOURNAL, but with little success. The net amount received during the past year was $198.12, and it was seen that but little could be expected from this source.

A Committee on Advertising was appointed by the Board of Government at the annual meeting, and to this committee is due the solution of the problem. At their suggestion the monthly notice mailed to each member of the Society, announcing the papers which are to be presented at the meetings, together with the names of candidates for membership, has been enlarged into the form of the present monthly bulletin, with which you are all familiar. The results were far in excess of anything which had been anticipated, as, after a few weeks, all the advertisements which could be reasonably used had been secured. The net income from these increased the income of the Society by about $800, double the amount necessary to provide for the anticipated deficit. The Board fully endorses the concluding portion of the committee's report which is as follows:

"It seemed to the committee, however, that in the *Bulletin* we have something better than an income producer. When the change in the monthly notices was proposed, it was at once evident that here was an opportunity to convey promptly to the membership certain information in regard to the Society and its library which heretofore had been lacking. It was decided to print in the *Bulletin* the records of all meetings, so that these records would be available to the membership much sooner than was possible when they were printed in the JOURNAL, and to make the library more valuable, a list of accessions has been published each month. A beginning has also been made towards publishing reviews of all new books added to the library. Thus has been started a publication which will be of real value and which will bring into closer touch with the Society those members who are not able to attend the meetings. There seems to be no reason why it may not be still further developed to contain, if not all the papers which are to be presented to the Society, at least such of them as can be secured far enough in advance for publication. With the experience of the past year your committee is convinced that this can be done without additional expense to the Society, as the advertising will more than pay the extra cost of publication."

The Board of Government believes that the practice begun some years ago of buying standard engineering books for the Society has proved beneficial, and would recommend that the sum of fifty dollars be appropriated for the purchase of such books for the coming year.

For the Board of Government,

FRANK W. HODGDON, *President.*

Abstract of the Treasurer's and Secretary's Reports for the Year 1906–1907.

CURRENT FUND.

Receipts:

Dues for 1906–1907	$3 935.50	
Dues for 1907–1908	59.00	
Sales of Journals	5.50	
Rent of rooms	1 000.00	
Advertisements	1 104.00	
Library fines	2.51	
Balance on hand, March 21, 1906	20.20	
		$6 126.71

Expenditures:

Rent	$1 995.00	
Lighting	46.81	
Association of Engineering Societies	1 472.99	
Printing, postage and stationery	936.21	
Salaries of Secretary, Librarian and Custodian	550.00	
Reporting meetings	163.37	
Stereopticon	65.00	
Annual dinner	74.00	
Books	50.28	
Binding	29.60	
Periodicals	30.50	
Clerical assistance for Librarian	34.00	
Furniture and repairs	35.40	
Incidentals	193.91	
Loan to Permanent Fund	63.95	
		5 741.02

Balance on hand, March 20, 1907	$385.69
Due from Permanent Fund	63.95
Amount to credit of Current Fund, March 20, 1907	$449.64
Amount to credit of Current Fund, March 21, 1906	20.20
Excess of receipts over expenditures during year	$429.44

PERMANENT FUND.

Receipts:

Thirty-two entrance fees, Society	$320.00	
One entrance fee, Sanitary Section	5.00	
Interest on deposits, savings bank	269.25	
Interest on bond	36.00	
Interest on deposit, Old Colony Trust Company	18.64	
Subscription to Building Fund	100.00	
Profits on shares in Co-operative Banks	496.05	
Loan from Current Fund	63.95	
Balance on hand, March 21, 1906	356.41	
		$1 665.30

Expenditures:

Merchants' Co-operative Bank, dues on shares......	$300.00	
Merchants' Co-operative Bank, profits on same.....	118.11	
Volunteer Co-operative Bank, dues on shares.......	300.00	
Volunteer Co-operative Bank, profits on same......	196.25	
Workingmen's Co-operative Bank, dues on shares...	300.00	
Workingmen's Co-operative Bank, profits on same..	181.69	
Franklin Savings Bank, deposit....................	42.71	
Warren Institution for Savings, deposit............	43.65	
Boston Five Cents Savings Bank, deposit..........	46.11	
Provident Institution for Savings, deposit..........	49.44	
Eliot Five Cents Savings Bank, deposit............	44.21	
Institution for Savings in Roxbury, deposit........	43.13	
		$1 665.30

PROPERTY BELONGING TO THE PERMANENT FUND, MARCH 20, 1907.

Twenty-five shares Merchants' Co-operative Bank............	$2 611.94
Twenty-five shares Volunteer Co-operative Bank.............	4 696.75
Twenty-five shares Workingmen's Co-operative Bank.........	4 315.17
Deposit in Franklin Savings' Bank.........................	1 252.88
Deposit in Warren Institution for Savings..................	1 280.49
Deposit in Boston Five Cent Savings Bank..................	1 352.47
Deposit in Provident Institution for Savings................	1 450.12
Deposit in Eliot Five Cents Savings Bank..................	1 297.10
Deposit in Institution for Savings in Roxbury...............	1 265.30
Republican Valley Railroad Bond, par value................	600.00
	$20 122.22
Due Current Fund..................................	63.95
Total value of Permanent Fund......................	$20 058.27
Amount of fund as per last annual report..............	18 813.33
Gain during the year...............................	$1 244.94

TOTAL PROPERTY OF THE SOCIETY IN THE POSSESSION OF THE TREASURER.

Permanent Fund....................................	$20 058.27
Current Fund......................................	449.64
Total..	$20 507.91
Amount as per last annual report........................	18 833.53
Increase during year.................................	$1 674.38

Report of Committee on Excursions.

Boston, March 20, 1907.

To the Members of the Boston Society of Civil Engineers:

The Committee on Excursions herewith respectfully submits its annual report.

Thirteen excursions have been made during the past year, as follows:

April 18, 1906. — Charles River Basin and Dam. Attendance, 42.

May 16, 1906. — Inspection of the Plant of the Boston Bridge Works, East Cambridge. Attendance, 25.

May 24, 1906. — Inspection of Wonderland Park previous to its opening to the public. Attendance, 226.

June 20, 1906. — Lawrence Worsted Mills, Lawrence, Mass. Attendance, 12.

July 25, 1906. — Blake & Knowles Pump Co., East Cambridge, Mass. Attendance, 8.

August 3 and 4, 1906. — Portland Stone Ware Company, Portland, Me. Attendance, 125.

September 1, 1906. — Paragon Park. Attendance, 110.

September 19, 1906. — Sewage Pumping Plant at Deer Island. Attendance, 28.

October 13, 1906. — Simplex Pile Driving, N. Y., N. H. & H. R. R., South Boston. Attendance, 30.

October 17, 1906. — Submarine Signal Company, Boston Harbor. Attendance, 18.

November 21, 1906. — Paving work on Washington Street. Attendance 25.

February 20, 1707. — Pipe Tunnels under Broad Canal, Cambridge. Attendance, 11.

March 20, 1907. — Washington Street Subway. Attendance, 32.

Total attendance, 692; average attendance, 53.

Thirty-six pages of the " New Engineering Work " have been published in the *Monthly Bulletin* of the Society during the past year, as against twenty-four for the previous year.

There is a cash balance of $9.32 in the hands of the Treasurer.

The Committee wishes to thank all those who have aided in this work.

Respectfully submitted,

L. Lee Street, *Chairman*,
Eugene E. Pettee,
J. O. DeWolf,
Clarence T. Fernald,
Edmund M. Blake, *Sec'y and Treas.*,
Committee on Excursions.

Report of the Committee on the Library.

Boston, Mass., March 20, 1907.

To the Members of the Boston Society of Civil Engineers:

The Committee on the Library begs leave to make the following report for 1906–1907.

Since the last annual meeting two hundred and ninety-seven (297) bound volumes have been placed upon the shelves. Of this number fifteen (15) books have been purchased and the remainder have been given to the Society.

During the year Mr. Clemens Herschel presented the Society with seventy (70) volumes. This splendid gift is now upon the shelves of the library and is a valuable addition.

Members have taken from the reading rooms for the purpose of reference two hundred and thirty-two (232) books during the past twelve months. This is an average of nineteen (19) per month, as compared with nineteen (19) per month of last year.

The present rules of the library allow a member to keep a book out five weeks. On account of the demand for some of the standard engineering text-books it seems that this period of five weeks is too long. If this rule is to be continued the Society should have several copies of some of the standard text or reference books in greatest demand, so that members of the Society may be properly accommodated. This solution of the problem, however, would entail considerable expense in the purchase of duplicate books, and a much better way is to reduce the time limit from five weeks to one week or else to limit the use of these standard engineering text-books to the reading rooms only. The committee recommends that the matter be referred to the Board of Government with power.

The committee also recommends that the sum of $50 be appropriated for the purchase of new reference or text books during the coming year.

Respectfully submitted,

FRANK P. McKIBBEN, *Librarian*,
FRANK B. SANBORN,
FREDERIC I. WINSLOW,
H. K. BARROWS,
HECTOR J. HUGHES,
Committee on the Library.

REPORT OF THE COMMITTEE ON ADVERTISEMENTS.

BOSTON, MASS., March 20, 1907.

To the Members of the Boston Society of Civil Engineers:

The Committee on Advertisements submits the following report of its doings for the year ending March 20, 1907.

The Treasurer's reports for the past three years have shown an excess of expenditure over income, the excess during the year ending March 21, 1906, being over $400. The existence of a considerable balance has heretofore prevented a deficit, but at the beginning of the present year the balance had been reduced to $20.20.

The last annual report of the Treasurer contained the following warning:

> "It will be seen from the above that our income has not equalled our expenditure. This was also true of the previous year. The considerable balance on hand at the beginning of the year is now nearly exhausted. . . . It would seem, therefore, that the only practicable method of caring for the deficit is either by increasing the income from advertisements in the JOURNAL or by reducing our current expenses."

It is plain that the expenses, which are practically constant, are capable of very little curtailment without impairing the usefulness of the Society, so that your Advertising Committee realized at the outset the importance of the task before them and that unless their efforts were

successful some way of decreasing the expenditures must be found or the annual assessment be increased.

Repeated efforts had already been made to increase the amount of advertising in the JOURNAL, but these efforts had met with but little success. The net amount received for advertising during the last year was $198.12. Experience has shown that few advertisers can be brought to see the value of an advertisement in a periodical such as the JOURNAL, which, in many cases, is not removed from the cover, and if removed from the cover is only to be put aside after an inspection of the table of contents.

It seemed to your committee, however, that the Society had a valuable advertising medium in the notices which are sent out each month, containing announcements of the coming meetings and excursions, the list of applications for membership and descriptions of new engineering work. These monthly notices are certain to be opened and read by practically every member of the Society, and advertisements in them are likely to reach a large proportion of the 600 members.

With the consent of the Board of Government the committee made arrangements for inserting a limited number of advertisements in these monthly notices, and the form of the notices was changed to the present *Monthly Bulletin*. The results were far in excess of anything which had been anticipated, and after a few weeks the committee ceased its labors, as it had a sufficient number of advertising contracts to insure a balance in the treasury at the end of the year instead of the threatened deficit, and it did not seem desirable to have too large a volume of advertising matter in the *Bulletin*. The contracts for advertising in the *Bulletin* amount to $1 120. No commissions have been paid and the only expense has been the extra expense of printing the *Bulletin*, which is in the vicinity of $300, making a total profit of about $800 for advertising. No effort has been made to secure additional advertising for the JOURNAL and the only income from this source has been from the renewal of contracts which had been previously made.

The efforts of the committee from a financial standpoint have been successful, and the treasurer's report shows, instead of a deficit of $400 which we had reason to anticipate, a balance of $400. It seems to the committee, however, that in the *Bulletin* we have something better than an income producer. When the change in the monthly notices was proposed it was at once evident that here was an opportunity to convey promptly to the membership certain information in regard to the Society and its library which heretofore has been lacking. It was decided to print in the *Bulletin* the records of all meetings, so that these records would be available to the membership much sooner than was possible when they were printed in the JOURNAL; and to make the library more valuable, a list of accessions has been published each month. A beginning has also been made toward publishing reviews of all new books added to the library. Thus has been started a publication which will be of real value and which will bring those members who are not able to attend the meetings in closer touch with the Society. There seems to be no reason why it may not be still further developed to contain, if not all the papers presented to the Society, at least such of them as can be secured for advance publication. With the experience of the past year your committee

is convinced that this can be done without additional expense to the Society, as the advertising will more than pay the extra cost of publication.

Respectfully submitted,

William S. Johnson,
F. A. Barbour,
S. E. Tinkham,
Committee.

Montana Society of Engineers.

Butte, Mont., February 9, 1907. — The regular meeting of the Society for the month of February, 1907, was held in the Society room at the appointed hour. Ex-President Dunshee presided. The minutes of the 20th annual meeting were read and approved. The application for membership in the Society of Harry Clifford Wilmot was read, and after its approval the Secretary was authorized to circulate the necessary ballot. Messrs. Lewis, McRae, Ring, Potter and Lindsay were elected to membership by a unanimous ballot. The trustees, to whom was referred the bill for a state geological survey, presented by Professor Bowman at the last meeting of the Society, made a verbal report, which was received. On motion the Society voted to endorse said bill for a state geological survey, now pending before the legislature of Montana. The Secretary was instructed to inform Representative Campbell, of Silver Bow County, who introduced the above-named bill, of the action of this Society in the matter.

The Secretary was authorized to forward the annual address of Ex-President Dunshee, and all other papers read at the annual meeting, as soon as obtained, to the Secretary of the Associated Societies for publication in the Journal at an early date.

The meeting then adjourned.

Clinton H. Moore, *Secretary.*

Technical Society of the Pacific Coast.

Regular meeting held March 1, 1907.

Called to order at 8.30 o'clock by President Franklin Riffle.

The minutes of the last regular meeting were read and approved.

The Secretary explained in detail the steps taken to hold the spring meeting in the city of Vallejo.

He spoke of the points of interest that could be visited from there, mentioning the navy yard, Starr's Mills, the Suisun and Napa Junction Cement Works and the Selby Smelting Works.

Mr. Marsden Manson thought that the localities of Oroville and Chico held out greater advantages for technical men, and that a visit to the big dredges and the mines would be preferred by most of the members.

This matter was discussed for some time by the members present, and the Secretary was finally instructed to address a circular letter requesting a choice of locality from the members themselves.

He is to ascertain how many will attend, and, if the promised attendance be sufficient to warrant the excursion, the information then wanted is the choice of the locality for holding the meeting.

The circular is to include also a request for professional papers to be read at the sessions of the spring meeting.

The Secretary thereupon read a paper by Past President J. Richards, entitled "Fire Prevention Apparatus," which was discussed by written papers by President Riffle and Mr. Thos. Morrin; and verbally by Marsden Manson, Luther Wagoner and others.

Mr. Wagoner thought that a copy of the paper and of the discussions should be sent to the chief of the fire department of the city.

After an interesting general discussion of modern methods to apply salt water from the bay either by pumping from barges or pumping stations, in case of fires in the city front districts, the meeting adjourned.

OTTO VON GELDERN, *Secretary.*

Association of Engineering Societies.

Vol. XXXVIII. | APRIL, 1907. | No. 4.

Engineers' Club of St. Louis.

St. Louis, March 6, 1907. — The 630th meeting of the Engineers' Club of St. Louis was held at the Club Rooms, 3817 Olive Street, Wednesday evening, March 6, 1907. President Fish presided. Twenty-three members and five guests were present.

The minutes of the 629th meeting were read and approved. The minutes of the 418th meeting of the Executive Committee were read.

The application for membership in the Club from Roy H. Pinkley was presented.

The Secretary read the following statement from the expert accountant instructed to audit the books of the Treasurer:

St. Louis, March 1, 1907.

Engineers' Club of St. Louis,
3817 Olive Street, City:

Gentlemen, — Attached hereto please find copy of statement covering operations from December 6, 1905, to December 5, 1906, submitted by your Secretary, dated December 5, 1906.

I have carefully examined the records for the period named, verified the statement and hereby certify its accuracy.

Yours very truly,
(Signed) Geo. W. Curry, *Accountant.*

The Secretary read a letter from the Civic League of St. Louis asking the Club to have representatives at a meeting to be held Saturday, March 2, in the office of the Business Men's League, to consider the need of a new charter for the city of St. Louis. The President of the Club announced that in response to this request he had notified the president of the Civic League that the Engineers' Club would be represented by Julius Pitzman, M. L. Holman and E. R. Fish.

The Secretary also read a most interesting and entertaining letter from Mr. O. W. Ferguson, a member of the Club, located in the Philippines. The Secretary was instructed to express the appreciation of the Club to Mr. Ferguson and to suggest to him that the Club would enjoy hearing from him as frequently as he finds it convenient to write.

Mr. Greensfelder moved that the Executive Committee be requested to examine Mr. Layman's presidential address with some care and make a report to the Club on the suggestions contained therein. Motion carried.

President Fish appointed the following Entertainment Committee: A. S. Langsdorf (chairman), R. L. Murphy, J. J. Lichter, Walter Robbins, S. D. Merton.

He also reappointed the Committee on Extension of Membership: W. H. Bryan (chairman), H. C. Toensfeldt, W. H. Henby.

Owing to the fact that Mr. Valliant was called east, he was unable to present his paper on the "Street Department; Its Organization and Its Work." Mr. Travilla and Mr. Childs had, however, prepared themselves to handle the entire subject in Mr. Valliant's absence, and a very entertaining and instructive discussion of the subject resulted. Mr. Travilla presented the legal side of the situation and the relation of the proposed changes in the charter to the work of the street department. Mr. Childs took up the bridge situation, methods of construction, length of life and cost of repairs, etc., for the different bridges and viaducts of the city. Both addresses were fully illustrated by lantern slides.

The discussion, which was participated in by Messrs. Pitzman, Von Maur, Toensfeldt, Harting, Fish, Fernald and Greensfelder, touched upon many points, such as the relation of the city to the sidewalks, the effect on the bridge construction of the steady increase in street car traffic, the overhead clearance above tracks, methods of laying and protecting gas service pipes in the streets, relation of the railway companies to bridge construction over their tracks and the effect of smoke upon bridges and methods of protection by means of paint, etc. Considerable discussion was provoked by the proposed new charter, some members even going so far as to desire immediate action on the part of the Club in this matter.

Adjourned.

R. H. Fernald, *Secretary.*

St. Louis, March 20, 1907. — The 631st meeting of the Engineers' Club of St. Louis was held at the Club rooms, 3817 Olive Street, Wednesday evening, March 20, 1907. President Fish presided. Forty-three members and thirty-two guests were present.

The minutes of the 630th meeting were read and approved and the minutes of the 419th meeting of the Executive Committee were read.

Mr. Roy H. Pinkley was elected a member of the Club.

An application for membership was presented by Mr. Carl L. Hawkins.

Mr. W. A. Baehr presented an exceedingly interesting illustrated paper on "Gas Engineering." The special points emphasized by Mr. Baehr are indicated by the following brief outline of the paper:

1. Brief historical outline of gas manufacture.

2. Mention of natural gas and its distribution.

3. Specific information concerning engineering of the manufacture and distribution of coal gas, water gas, by-product coke oven gas, producer gas, oil and blast-furnace gas, acetylene and miscellaneous.

4. The handling of material, types of apparatus, methods of distribution.

5. Thermal calculations concerning high temperature estimates.

6. Table of specific heats of gas at high temperatures, according to latest researches.

7. Specific data on the method of distributing gas in St. Louis.

8. Slides, showing drawings and photographs of various installations throughout the country.

The discussion, which was participated in by Messrs. Bryan, Robert Moore, McCulloch, Fish and Baehr, brought out the following points:

The question of deterioration of coal when stored either under cover or exposed to the weather was raised. It was stated that little data were available on this point. Mr. Baehr stated that the gas company did not find it necessary to store the coal under cover in St. Louis.

An effort was made to secure information relating to storing of coal under water.

In replying to a question regarding the relative advantages of water gas and coal gas, Mr. Baehr stated that the two are about alike. There is more hydrogen in the water gas and it is, consequently, not as good for gas engines, but either gas can be used for other purposes.

Other points which were touched upon in the discussion related to the life of gas mains, methods of protecting pipes under ground, methods of protecting from corrosion steel work in the retort houses and the possible use of gas for heating the water in hot-water heating systems.

Adjourned.

R. H. Fernald, *Secretary.*

The Civil Engineers' Club of Cleveland.

Annual Meeting, March 12, 1907, at Case School of Applied Science, called to order by President Miller about 9 p.m. Present: 52 members and 26 ladies and other visitors. Reading of minutes of previous meeting dispensed with, as was also reading of applications for active membership of Frederick D. Leslie and William Stanley Ferguson, both approved by the Executive Board.

The tellers, Messrs. Cadwell and Schowalter, reported the election of the following officers of the Club for the ensuing year:

President — Charles H. Wright.

Vice-President — Willard B. Beahan.

Secretary — Joseph C. Beardsley.

Treasurer — Walter M. Allen.

Librarian — Joseph R. Poe.

Directors (term expires 1909) — George T. Nelles, Andrew B. Lea: and the election of Sam. W. Emerson to active membership.

Printed copies of the financial reports of the Secretary and Treasurer were submitted and are appended hereto, as is also the Secretary's report on membership.

The report of Mr. Nelson, the Librarian, was read by the Secretary.

The President's address, "Recent Developments of Physical Science," was then given by Dr. Miller. It was an interesting history of the development of the electron theory of the constitution of matter and was illustrated by many beautiful and interesting experiments.

Before and after the meeting the members had the privilege of inspecting the new Rockefeller Physical Laboratory, which was opened for the first time to the public on this occasion.

Refreshments were served after adjournment.

Adjourned.

Joe. C. Beardsley, *Secretary.*

Financial Reports of Secretary and Treasurer for Year Ending February 28, 1907.

SECRETARY'S REPORT.

Permanent Fund.

Balance, March 1, 1906		$1 558.48	
Fees	$110.00		
Interest	64.04	174.04	
Transferred to General Fund			$600.00
Balance, February 28, 1907			1 132.52
Total		$1 732.52	$1 732.52

General Fund.

Balance, March 1, 1906		$11.68	
Dues, Active	$1 845.00		
Associate	112.00		
Corresponding	140.00		
Delinquent	110.00	2 207.00	
1905 Bills			$222.90
Advertising		116.00	20.80
Books and periodicals		5.00	22.75
Program		107.50	274.75
Incidentals			6.90
Journal		1.50	491.88
New quarters			459.02
Furniture and Fixtures			7.00
Reporting			10.00
Printing			270.93
Postage			90.10
Stationery			3.15
Associated Technical Clubs			742.50
Secretary			200.00
Telephone (extra name)			16.59
Taxes			11.34
Interest, $2.41; Miscellaneous, $1.75		4.16	
Transferred from Permanent Fund		600.00	
Balance, February 28, 1907			202.23
		$3 052.84	$3 052.84

Summary.

March 1, 1906, Balance, Permanent Fund	$1 558.48	
March 1, 1906, Balance, General Fund	11.68	
Receipts, Permanent Fund	174.04	
Receipts, General Fund	3 041.16	
Disbursements, Permanent Fund		$600.00
Disbursements, General Fund		2 850.61
February 28, 1906, Balance, Permanent Fund		1 132.52
February 28, 1906, Balance, General Fund		202.23
	$4 785.36	$4 785.36

Bills Receivable.

From members (dues)	$376.00

Bills Payable.

Associated Technical Clubs, January 1 to April 1, 1907	$247.50
The Warner & Swasey Co. (Periodicals)	14.65
Association of Engineering Societies	65.00
	$327.15

Respectfully submitted,

JOE. C. BEARDSLEY, *Secretary.*

TREASURER'S REPORT.

Permanent Fund.

Receipts:			
Balance on hand March 1, 1906	$1 558.48		
Entrance fees	110.00		
Interest	64.04	$1 732.52	
Expenditures:			
Furnishing new club room		600.00	
Bal. on hand February 28, 1907,		$1 132.52	$1 132.52

General Fund.

Receipts:			
Balance on hand March 1, 1906	$11.68		
From Sec'y, to February 28, 1907,	2 441.16		
From Permanent Fund	600.00	$3 052.84	
Expenditures		2 850.61	
Bal. on hand February 28, 1907,		$202.23	202.23
Grand total on hand February 28, 1907			$1 334.75

Respectfully submitted,

W. M. ALLEN, *Treasurer.*

Montana Society of Engineers.

BUTTE, MONT., MARCH 9, 1907. — The regular meeting of the Society for the current month was held in the Society room, 225 North Main Street, on the above-named date at the usual hour. Ex-President Goodale presided. Quorum present. The minutes of the February meeting were approved as read. The application of Harry Hamilton Cochrane for membership in the Society was read, and after approval the Secretary was instructed to issue the necessary ballots. Harry Clifford Wilmot was elected a member of the Society by a unanimous vote. The request of the Technology Club of Syracuse, N. Y., for an exchange of club room and library privileges was read and granted. The Secretary of this Society was instructed to solicit the same favors from various engineering societies in behalf of any Montana Society engineers who may be temporarily situated where said societies are established.

The Society then adjourned.

CLINTON H. MOORE, *Secretary.*

Association of Engineering Societies.

Vol. XXXVIII. | MAY, 1907. | No. 5.

PROCEEDINGS.

Engineers' Club of St. Louis.

St. Louis, April 3, 1907. — The 632d meeting of the Engineers, Club of St. Louis was held at the Club rooms, 3817 Olive Street, Wednesday evening, April 3, 1907, at 8.15 o'clock. President Fish presided. Forty-eight members and twenty-six visitors were present.

The minutes of the 631st meeting were read and approved and the minutes of the 420th meeting of the Executive Committee were read.

The application of Edwin L. Smalley for membership in the Club was presented.

Mr. Carl L. Hawkins was elected a member of the Club.

The following resolution was presented:

" *Whereas*, there is under the auspices of the Civic League a movement under way looking toward the revision of the charter of the city of St. Louis, and as the members of this Club, both as citizens and engineers, have a great interest in this movement, and, having been invited to participate through two representatives in a meeting to consider ways and means to bring about such a revision, therefore be it resolved, that it is the sense of this meeting that a revision of the charter of the city of St. Louis is needed and advisable and that the President of this Club be instructed to appoint two delegates to represent the Club at such meetings as may be held under the auspices of the Civic League for the above-named purpose."

This resolution was adopted unanimously.

Mr. Robert Moore, who had just returned from a visit to Panama, presented a most interesting paper entitled " Notes of a Recent Trip to Panama." He discussed the canal project as originally proposed by the French and took up more or less in detail the development and changes in the proposed plans up to the present time. The paper was fully illustrated by maps, charts and lantern slides, which gave an excellent idea of the various plans proposed and the work that has been accomplished. Mr. Moore stated that of about 80 000 000 cu. yd. of earth moved by the French, only about 40 000 000 are usable, and that a large portion of the remainder will have to be rehandled. He gave a very complete description of the conditions on the Isthmus when the United States took the matter in charge. The tools and appliances found were obsolete, sanitary conditions bad and everything pertaining to comfort and safety from illness had to be carefully considered. There was little on the ground of service in this direction with the exception of about 2 000 small houses,

which were repaired and used. A good layout of hospitals was arranged among these houses. All food has to be brought in from the outside, as about the only thing raised on the Isthmus is bananas, and the supply of these is small. The government had to supply all necessary sanitary measures, police protection, hospitals, schools, churches, etc. At the present time there is a small government of its own on the Isthmus. The police arrangements are excellent and the general conditions are exceedingly satisfactory.

White labor seems to be very abundant. All the Italians and Spaniards desired can be secured. The white labor is proving much more efficient than black and the whites are receiving about three times the pay of the negroes. Mortality of the negroes is three to four times that of the white, pneumonia being the principal cause.

The early French proposition was for a canal about 29.5 ft. deep. Later plans increased this to 35 ft. and the present plan calls for 40 ft. The estimated cost of the proposed sea level canal is $247 000 000, requiring from twelve to thirteen years for completion. The plan, which is being carried out, *i. e.*, the lock canal, is estimated to cost $140 000 000. It is expected that this will be sufficiently completed for ships to pass through in eight years, *i. e.*, early in 1915. Not only is the lock canal cheaper, but the proposed construction will enable large ships to pass through much more quickly than would be possible with the sea-level canal.

Mr. Moore paid a high tribute to Engineer Stevens and to his corps of assistants, the latter including two members of the Engineers' Club of St. Louis, Messrs. Comber and Maltby.

Adjourned.

R. H. FERNALD, *Secretary.*

ST. LOUIS, APRIL 17, 1907. — The 633d meeting of the Engineers' Club of St. Louis was held at the Club Rooms, 3817 Olive Street, Wednesday evening, April 17, 1907, at 8.15 o'clock. In the absence of the President, Vice-President Brenneke presided. Thirty-nine members and fourteen visitors were present.

The minutes of the 632d meeting were read and approved and the minutes of the 421st and 422d meetings of the Executive Committee were read.

The following applications were presented: James Stewart Kuhn for associate membership, Fred Oscar Pahmeyer for junior membership.

Mr. Edwin L. Smalley was elected member.

The recommendation of the Executive Committee that the committee be authorized to publish the Club's bulletin at an expense not to exceed $250 was approved.

Mr. W. H. Bryan, chairman of the Committee on Extension of Membership, made a complete report. The committee presented a list of approximately four hundred names of men who might be interested in the Club. The report made special recommendations regarding the methods of procedure in order to increase the present membership. It was moved by Mr. Greensfelder that the report of the committee be accepted and turned over to the Executive Committee for further action and the Committee on the Extension of Membership be discharged. Motion carried.

The committee appointed by the Club to assist in framing a set of regulations covering reinforced concrete construction in the city of St. Louis made a full report through its chairman, Mr. H. C. Toensfeldt. The report of the committee was accepted and the committee honorably discharged.

The business of the evening was devoted to a careful consideration and discussion of the specifications for reinforced concrete structures, prepared by the joint committee and embodied in the building ordinances of the city of St. Louis. These specifications had been printed by the Club and a copy sent to each member. They were taken up for discussion paragraph by paragraph, Mr. Toensfeldt, chairman of the committee, taking the lead. A spirited discussion resulted, and was participated in by a large majority of those present, Messrs. Purdon and Lindau having reduced their remarks to writing. Letters relating to this subject were received and read from Messrs. Viterbo and Traber. Mr. Greensfelder suggested the advisability of publishing this report and full discussion in the JOURNAL.

The Club adjourned at a late hour.

R. H. FERNALD, *Secretary.*

The Civil Engineers' Club of Cleveland.

REGULAR MEETING, April 9, 1907, at the Club rooms, called to order by President Wright, at 8 P.M. Present, forty members and visitors.

Minutes of two preceding meetings read and approved.

The tellers, Messrs. Neff and Wight, reported the election of Frederick D. Leslie and William Stanley Ferguson to active membership.

The application of Mr. Nathan C. Beckerman for active membership, approved by the Executive Board, was read.

The paper of the evening, "State Protection of the Purity of Inland Waters," was read by Mr. R. Winthrop Pratt, engineer of the Ohio State Board of Health.

The discussion was opened by Dr. Friedrich, City Health Officer, who held that with all possible freedom from contamination that could be obtained, there would still have to be filtration for all public water supplies, even where the supply was as ample in volume as it is where it is taken from a body as large as any of the great lakes.

Colonel Townsend, United States Engineer, told of the dumping of dredged material within less than 2 miles of the city's intake crib, much of this material coming from the river and being of fully as objectionable character as sewage. Mr. Rice told of the dumping of night soil in the same manner, and Messrs. Ritchie and Hoffman also took part in the discussion.

On motion of the Secretary the matter of the dumping of dredged material and night soil in the vicinity of the water works intake was referred to the Committee on Water Pollution for investigation and report.

On motion of the Secretary, Mr. Pratt was tendered a vote of thanks for his very able and interesting paper.

Adjourned.

JOE. C. BEARDSLEY, *Secretary.*

Boston Society of Civil Engineers.

Boston, April 17, 1907. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 8 o'clock p.m., President Edward W. Howe in the chair; seventy-six members and visitors present.

The record of the last meeting was read and approved.

Messrs. George H. Brazer and Edward W. Hadcock were elected members of the Society.

The Secretary reported for the Board of Government the appointment of the following committees:

Committee on Excursions — L. Lee Street, E. M. Blake, C. T. Fernald, E. E. Pettee and L. B. Manley.

Committee on the Library — F. I. Winslow, Chas. Saville, N. S. Brock, H. E. Cowan and H. R. Stearns.

Committee on Quarters — Desmond FitzGerald, E. W. Howe, G. A. Kimball, F. W. Dean and F. W. Hodgdon.

Committee on Advertisements — W. S. Johnson, S. E. Tinkham and F. A. Barbour.

Board of Managers, Association of Engineering Societies — S. E. Tinkham, *ex officio*, Dexter Brackett, C. W. Sherman, G. A. Kimball, H. P. Eddy and A. T. Safford.

Mr. Fred. Brooks, for the Committee appointed to prepare a memoir of Nelson Spofford, a member of the Society, presented and read its report.

Mr. George B. Francis read the paper of the evening, entitled "Pennsylvania Terminal Station in New York City, and the Engineering Problems Connected Therewith." The paper was illustrated by a large number of lantern slides.

Adjourned.

S. E. Tinkham, *Secretary.*

Montana Society of Engineers.

Butte, Mont., April 13, 1907. — The regular meeting of this Society for April was held at the called time and place. Trustee Wilson presided. Attendance good.

Minutes read and approved.

Harry Hamilton Cochrane elected to membership by a unanimous vote.

Application for membership in Society of James Humes read, approved and ballots ordered circulated.

Several letters from societies granting request of this Society for exchange of library and reading-room privileges read and appreciated. Society adjourned.

Clinton H. Moore, *Secretary.*

Association of Engineering Societies.

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PROCEEDINGS.

Engineers' Club of St. Louis.

St. Louis, May 1, 1907. — The 634th meeting of the Engineers' Club of St. Louis was held at the Club Rooms, 3817 Olive Street, Wednesday evening, May 1, 1907, at 8.15 o'clock. President Fish presided. Twenty-seven members and ten visitors were present.

The minutes of the 633d meeting were read and approved.

The application of Mr. William B. Ittner for associate membership was presented.

Mr. James Stewart Kuhn was elected an associate member and Mr. Fred Oscar Pahmeyer, junior member.

The paper of the evening was by Mr. W. H. Rohwer on "Deep Foundations for Bridges and Buildings." The author reviewed the entire subject of deep foundations at some length, and described in detail some of his own work in this field, notably the foundations for the Arkansas River and White River bridges. A discussion was called forth by the paper, which was participated in by Messrs. Purdon, Henry, Flad and Greensfelder.

Adjourned.

Hans C. Toensfeldt, *Secretary pro tem.*

St. Louis, May 15, 1907. — The 635th meeting of the Engineers' Club of St. Louis was held at the Club Rooms, 3817 Olive Street, Wednesday evening, May 15, 1907, at 8.15 o'clock. President Fish presided Sixty members and thirteen visitors were present.

The minutes of the 634th meeting were read and approved.

Prof. A. S. Langsdorf, chairman of the Entertainment Committee, made an informal report regarding proposed trips to Washington University and to the plant of the Illinois Glass Works.

The following applications were received: Schantl, Hans (member); Sweetser, Ernest Osgood (member); Morrison, Henry Craig (Junior).

Mr. F. B. Maltby, principal assistant engineer Isthmian Canal Commission, presented an unusually interesting and instructive paper entitled "Progress of the Work on the Panama Canal under the Administration of Mr. J. F. Stevens." Many queries were made of Mr. Maltby

regarding conditions, etc., in the canal zone, the discussion being participated in by Messrs. Fish, Layman, Trepp, Barwick, Robert Moore, Flad, Hinckley, Bouton and Hoffman.

Adjourned.

R. H. Fernald, *Secretary.*

Boston Society of Civil Engineers.

Boston, May 15, 1907. — A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 8 o'clock p.m., President Edward W. Howe in the chair, 81 members and visitors present.

The record of the last meeting was read and approved.

Messrs. Thomas F. Bowes, Charles S. Bryer, Frederick A. Leavitt, Ernest M. Moses, Daniel Scouler, Jr., and Harrie L. Whitney were elected members of the Society.

Prof. George F. Swain, for the committee appointed to prepare a memoir of John E. Cheney, a member of the Society, presented and read its report.

The President announced the deaths of Charles H. Haswell, an honorary member of the Society, who died May 12, 1907, and Frank W. Upham, who died May 3, 1907. By vote the President was requested to appoint committees to prepare suitable memoirs. The following committees were appointed: On memoir of Mr. Haswell, Messrs. Desmond FitzGerald, Clemens Herschel and Ira N. Hollis. On memoir of Mr. Upham, Messrs. I. T. Farnham and Rowland H. Barnes.

Mr. Thomas MacKellar read the first paper of the evening, entitled, "The Simplex System of Concrete Piling." Mr. Charles R. Gow read the second paper, which dealt with the general subject of concrete piles. Both papers were illustrated with lantern slides.

In the general discussion which followed the reading of the papers, Mr. Frank B. Gilbreth, in response to an invitation of the President, spoke briefly of his experience in driving concrete piles. He also spoke of the large amount of concrete work now being done at San Francisco, and expressed his regrets that so much of it was in the hands of men who were inexperienced in this kind of work.

Adjourned.

S. E. Tinkham, *Secretary.*

Toledo Society of Engineers.

Toledo, April 12, 1907. — Meeting called to order at 8.20 p.m. by Vice-President H. E. Riggs.

Secretary read the minutes of the Society meeting of March 8, 1907, which were approved as read.

Secretary then read the report of the Board meeting of April 5.

Chairman of Finance Committee, Mr. C. L. Gates, being absent, the report of that committee was read by the Secretary and accepted as read. (See report on file.)

Mr. Davis, chairman of Publication Committee, read report of that committee, which was accepted as read. (See report on file.)

Library Committee, Mr. H. E. Riggs chairman, reported no meetings of committee held since new order of business.

Mr. Davis, as chairman of Furnishing Committee, reported that an order had been placed with the Lion Store for a full set of curtains, but they were one pair short, which had been ordered from the mill but had not yet arrived.

Under new business:

Committee on Annual Banquet reported. (See report on file.) Mr. M. J. Riggs moved that Publication Committee arrange for annual banquet, time, place and all details to be settled by committee. Mr. Davis called for suggestions as to expenses, etc., in regard to banquet.

The motion being put, it was unanimously carried.

The chairman of the evening, in a few well-chosen remarks, then introduced Mr. Faro Gage, of Columbus, who spoke on the subject of "Civic Improvements." (See paper on file.) Mr. Gage was heard with a great deal of interest and his paper highly appreciated by those present.

The chairman then introduced Mr. E. O. Fallis, who read a paper on the subject of "Municipal Improvements." This paper was illustrated with very instructive stereopticon views. (See paper on file.) After Mr. Fallis' paper a lengthy and interesting discussion took place, in which Messrs. Fallis, Gage, M. J. Riggs, Sherman, Gates, Tonson, Langdon and Hiett took part. Mr. Brumback, of the Chamber of Commerce, spoke with emphasis on the subject of Civic Improvements as concerns the Chamber of Commerce. He was followed by Mr. Dunham, clerk of the Council, who gave the views of the Council on this subject.

Mr. M. J. Riggs moved that the chairman appoint a committee of three or four to confer with the Chamber of Commerce on the above subject. This motion was seconded and carried unanimously. Chairman appointed Messrs. Fallis, M. J. Riggs, Davis, Sherman and Gould.

There being no further business, the meeting adjourned.

JOHN C. OLIPHANT, *Secretary.*

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